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ON THE BRIGHTNESS OF THE SKY AND THE TOTAL AMOUNT OF STARLIGHT.

AN EXPERIMENTAL STUDY

L. YNTEMA.

GEBROEDERS HOITSEMA. — 1909. — GRONINGEN.

ON THE BRIGHTNESS OF THE SKY AND THE TOTAL AMOUNT OF STARLIGHT.

AN EXPERIMENTAL STUDY

PROEFSCHRIFT

TER VERKRIJGING VAN DEN GRAAD VAN

DOCTOR IN DE WIS- EN STERREKUNDE

AAN DE RIJKSUNIVERSITEIT TE GRONINGEN

OP GEZAG VAN DEN RECTOR MAGNIFICUS

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GEBOREN TE CORNWERD.

GEBROEDERS HOITSEMA. — 1909. — GRONINGEN.

AAN MIJNE MOEDER

EN

AAN MIJNE VROUW.

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INTRODUCTION.

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1. *Aim of the investigation.*

The apparent distribution of the stars is a fundamental question of siderea astronomy. One of the elements in its derivation must be the variation of the number of stars of every order of magnitude with the galactic latitude. Up to the present time the most extensive study about this subject has been published by Prof. KAPTEYN in **No. 18** *of the Publ. of the Astronomical Laboratory at Groningen*: *On the number of stars of determined magnitude and determined galactic latitude.* Interpolation formulae for those magnitudes, for which direct observation has not furnished us with complete data, are derived from all the available data of observation The result is given in Table 1 at the end of the paper. About this table the author remarks on p. 39: "we may say that our „table represents the data of observation with fair accuracy from magnitude 3.5 „down to the faintest stars about which we have any data (say to magn. 15.0). „We have extended the table to the 19th magnitude, although of course it is well „understood that the values beyond the 15th magnitude become rapidly more „uncertain."

Now it is probable, that sooner or later we shall have far more extensive materials including stars down to the 17th and 18th magnitude, but even then we will not have reached the utmost limit, even supposing that there is such a limit. There is no doubt that at all times both the photographic and the visual methods of observation will have a certain limit. As to the faintest stars we shall consequently always be compelled to make use of some "law of progress". For that purpose various astronomers have started from a more or less scientific hypothesis. Prof. KAPTEYN has extrapolated the numbers of the faintest stars from the empirical formulae furnished by the stars brighter than 15.0.

Now the question is, Is there any way of empirically checking and correcting these extrapolated numbers?

Apriori there seems to be reason to suppose, that the question may be solved by a photometric determination of the brightness of the background of the sky at night. It is well known that the faint, diffused light of the Milky Way is due to countless telescopic stars. But neither is the background of the sky by any means black at various distances from the Milky Way. If we admit, that on clear and moonless nights there are no other luminous bodies in the sky than the stars, the total light of the sky will be equal to the total amount of star-light, corrected for absorption and reflection in the atmosphere. If we could determine the quantity of light, received pro square degree, we should have got a fair check on any theory of the apparent arrangement of the stars.

However, provisional investigations, made by Prof. Newcomb and others, show clearly that the question must be much more complicated.

The aim of the present investigation is to study the relation between the brightness of the sky at night and the total amount of star-light pro square degree.

The problem is to be divided into two parts:

1⁰ the determination of the relative brightness of different portions of the sky;

2⁰ the determination of the absolute brightness of the sky, that is to say the determination of the amount of light, received pro square degree, in terms of a star of determined magnitude.

Both visual and photographic methods may be used. Probably the result of both methods will not agree, but their differences may help to trace the causes of the anomalies we meet in our investigation. I have tried both ways to make relative and absolute measurements. Before explaining these measures I will give a short account of earlier investigations on the subject.

CHAPTER I.

2. *Historical notes.*

As far as I know, F. G. W. **Struve** has been the first, who has called attention to the importance of a photometric determination of the brightness of the sky. On p. 93 of his celebrated *Etudes d'astronomie stellaire* (*St. Pétersbourg* 1847) he remarks: "Pour faire avancer notre connaissance de la constitution de „la voie lactée, il est à désirer que *les intensités relatives*, soit des étoiles dans „les différentes classes de grandeur apparente, soit *du fond du ciel*, dans les „différentes directions, fussent déterminées *par la voie purement photométrique*."

No attempts worth mentioning seem to have been made until some years ago when Prof. **Newcomb** drew attention to the subject [1]. While spending a summer vacation in the country, he made some experiments. His investigations are published in an article of the *Astrophysical Journal*, *Vol. XIV*, *Dec.* 1901, entitled: „*A rude attempt to determine the total light of all the stars.*" A brief account of these investigations will first be given.

Relative as well as absolute determinations by visual methods have been made. As to the relative ones the following two ways were tried.

1st. With sliding tubes of a small spy-glass, which could be extended to lenghts varying between 30 and 70 centimetres. The ends of the tube were covered with caps having in them openings with a diameter of 5 to 8 millimetres. In different directions the minimum portion of the sky, certainly visible, was determined. With regard to this method Prof. **Newcomb** says at the end of the paper: "It is subject to a large probable error in the individual observations, „but by repeating them, pointing in rotation on different regions of the sky, I „think that constant error would be avoided. This seems to be the method which „is open to least doubt." And yet some pages before, the following important objection is made: "There is one uncertain element in the interpretation of the

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[1] Attempts similar to those made by **Horner** (*Monatliche Correspondenz*, *Tome X p. 220 Sept. 1804*) and **Houzeau** (*Uranographie générale*, *Ann. de l'Obs. de Bruxelles*, *Nouv. Série*, *Tome I*), which only bear upon the relative brightness of different portions of the Milky Way, need not be considered here. For our purpose they are of no importance, as will be shown afterwards.

„method, the effect of the size of a surface on its visibility under a faint illumination. „If we have a definite quantity of light it will be more and more distinctly visible „as it is more condensed. In other words, if we suppose a series of illuminated „circular disks subtending various angles, the amount of light necessary to make „one of them visible will be greater, the greater the surface. But this amount „will not increase in proportion to the surface because the visibility of every „portion is re-enforced by the illumination of the surrounding portions. I am not „aware that any determination has ever been made of the law governing this case. „Our result, therefore, must be in part hypothetical."

2nd. The second method was to determine the brightness of various portions of the sky by their juxtaposition in small mirrors. Dark glasses were used to obtain equally illuminated fields.

The general result of these methods was that the brightness of the Milky Way was about twice that of the rest of the sky, while no difference could be detected in the illumination beyond about 25 degrees from the Galaxy.

At the end of the article the author suggests a third method, *viz.* by comparing various portions of the sky with a faintly illuminated "canopy", care being taken to use a light of the same colour as the sky He thinks, that in this way relative determinations can be made with fair accuracy, but he fears, it will be impossible to fix the albedo of the "canopy" with such precision, that the method can be used for absolute measures.

As to the second part of the problem, the determination of the brightness of the sky in terms of star-light, Prof. NEWCOMB continues: "As it is impossible „to concentrate the light of a surface into a small space, we must, in order to „compare light of a star and sky, spread that of the star out by means of a „lens; a concave lens is the best for this purpose [1]). In doing this we meet „with the difficulty, that the expanded light of the star is superposed upon that „of the sky around it. A device was therefore adopted of cutting down the „brightness of the expanded image by an absorbing glass to that of the sky. In „doing this, however, the eye is likely to be deceived by contrasts. It need „hardly to be said that only one eye must be used in such comparisons. To „avoid error from this source the system finally adopted was this: By means of „a concave lens the light of a star is spread out into an image of known angular „diameter. This image is then reduced by being viewed through a dark glass, „transmitting the fraction h of the light. Thus we have in the field of vision a „diffused image S of the star and of the sky arround it, the whole enfeebled by „the fraction h. Alongside of this arrangement let there be a second, consisting „of the same or an equally dark glass, having in it an opening of which the „apparent angular diameter shall be the same as that of the diffused image of „the star. We have thus in the field of view two similar images. A star is to „be taken such that the two images shall appear equal."

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[1]) The method, used in the present investigation, shows that it is not impossible to pass from an illuminated surface to an illuminated point.

Afterwards the author refers to this method. It is improved by placing a convex lens between the second dark glass and the observer's eye, while it is recommended to attach the whole to a telescope with equatorial mounting.

The results of this method are rather discordant. After an ample discussion of the observations the general conclusions are summed up as follows:

„Taking as the unit of surface that of a circle one degree in diameter, and „measuring its brightness by the amount of light, received from it, in terms of „the light of a star of magnitude 5.0 as unity, the brightness of the sky near the „galactic poles is 0.9 with a mean error ± 0.2.

„In the brighter agglomerations of the Galaxy, measuring the brightness in „each case by its mean value in a circle not less than 5 degrees in diameter, its „brightness is equal to that near the galactic pole, plus a quantity which probably „lies between 1.0 and 1.5" [1]).

The results obtained by Prof. NEWCOMB differ widely from those, which he had expected. First, according to existing photometric and statistical data he could not but suppose, that the sky at 30 degrees galactic latitude ought to be more than twice, and in the agglomerations of the Milky Way, ten times as bright as at the poles. Secondly, „the impression one gets by simply looking at „the Galaxy is certainly that of being several times brighter than the background „of the sky".[2])

Prof. NEWCOMB explains partly the paradoxical character of the results by the fact, that the light received from any region of the sky is composed of two parts, the one reaching us directly from the telescopic stars, the other being reflected by the atmosphere from all the stars above the horizon. The author attempted "in a way even more rude than that of the rest of the observations" to determine the proportion n of the light received directly from the sun and the total amount of diffused sky light. He found $n = 10$. Admitting this value, the results are not materially modified.

Finally Prof. NEWCOMB puts the dilemma: „On the whole it seems either „that my observations are wholly at fault — erroneously by an amount which I „should find it difficult to account for — or we must materially modify our con-

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[1]) I take this occasion to draw the attention to the distinction, which is made throughout Prof. NEWCOMB'S paper, between the brightness of the Galaxy and that of the background of the sky. A similar distinction is made in the papers of most astronomers, who have specially studied the appearance of the Milky Way. The impression is made, that the illumination of the apparent Galaxy is effected by two sources of light, the Galaxy itself and the general background of the sky. If this were the case, we should first of all have to fix the exact boundaries of the Milky Way. On the other hand, does not the distinction imply the idea, that the stars which form the Milky Way belong to a system different from the other stars? Prof. NEWCOMB'S own opinion, however, is that "the Milky Way is no „merely local phenomenon, but closely connected with the entire constitution of our stellar system." (*Cf. The Stars* by SIMON NEWCOMB, pag. 250).

[2]) It is remarkable, that indeed most persons are of the same opinion. Among others, in the paper quoted above, STRUVE finishes his conclusions as follows: ". . . . . le fond du ciel dans la direc- „tion du pôle n'a pas même un sixième de la lueur de la voie lactée.

„Toutes ces conclusions sont admirablement conformes à l'apparence générale de la voûte céleste."

"clusions from the combination of star-gauges with the existing photometric "estimates of star-light".

The article of Prof. Newcomb attracted the attention of G. J. Burns. As he had already made studies on the subject during four years, he gives a brief account of these in *Astrophysical Journal*, *Vol. XVI*, *Oct.* 1904. His first attempt to determine the relative brightness of the sky was based on the principle of Abney's revolving sectors. As he obtained no results of any value by this method, he next tried to make use of several pieces of clear glass. He looked at some part of the Milky Way through one, two, three or more pieces of glass and compared its brightness, seen through the glass, with some other portion of the sky. In this way he found the Milky Way from two to three times brighter than the rest of the sky. He has also been unable to detect any difference in the luminosity of the non-galactic sky.

As to the determination of the absolute brightness the method adopted was to compare the brightness of the sky with that of a star, which was brought out of focus in a telescope. A suitable star was taken and brought out of focus to such an extent as to make the brightness of the apparent disk equal to that of the sky. The latter was viewed through a hole in a black screen which subtended an angle nearly equal to the angular diameter of the disk of the star. One eye was applied to the telescope and the other observed the sky. Each observation was the mean of a right-eye and a left-eye observation. The conclusion of the rather discordant observations is, that half a square degree of the non-galactic sky gives as much light as a star of the fifth magnitude. Burns believes, that the discordance of his observations is largely due to difference in colour between the sky and the image of the star.

Besides, Burns has published some short communications on the subject in the *Journal of the British Astronomical Association*. They are chiefly relative to a photographic treatment of the question. I think there is no reason to discuss these papers. I wish only to quote, what Burns says about the causes of the illumination of the sky (*Journal of the British Astr. Ass. Vol. XVI* No. 8, pp 308--309):

„The generally received opinion is that the light of the sky is due to the „light of telescopic stars not separately visible. But there appear good reasons „for believing that the luminosity of the sky by night is partly due to some „other cause. 1st. If the luminosity were entirely due to the light of telescopic „stars, we should expect it to diminish near the horizon, just in the same manner „as the brightness of the stars diminishes and for the same reason, *viz.*, the „greater absorption of light by the earth's atmosphere. As a matter of fact, the „exact opposite is the case. The brightness of the sky increases perceptibly near „the horizon. One of our Members, Mr. Backhouse, has noticed this fact, and „I have observed it myself in a locality where there was no possibility of seeing „reflected light from street lamps or other similar sources. If however, the luminosity in question is partly due to a stratum of luminous particles at a moderate „distance from the earth, then this effect would naturally follow. 2nd. Another reason „for believing that the light of the sky is partly due to some other cause than

„starlight is that it has been observed to vary in brightness. It has been recorded „that in August 1880 the sky was unusually bright, and if this is an actual „fact, it is obvious that the variable part of the luminosity must have had some „other origin than the light of the stars"[1]).

While engaged in photometric work at the Lick Observatory, SIDNEY D. TOWNLEY has made a few determinations by photography. His investigations are published in the *Publ. of the Astron. Soc. of the Pacific*, *Vol. XV p.* 13.

To determine the brightness of the sky in terms of star-light, a first attempt was made by photographing a star a few inches behind the focus of a telescope. After the exposure of a rapid plate for one hour on Vega, an impression of about two centimetres was formed on the plate, but it was found that the light was very unevenly distributed. The impression was made up of small dark granules, surrounded by lighter circles. A straight "gash" ran nearly across the centre of the circle, and there were also several smaller curved "gashes." This method was therefore abandoned and the following simple one adopted.

„Both lenses were removed from the Crocker photographic telescope, and „several cardboard diaphragms were made, so that they could be attached to the „end of the telescope-tube. An exposure of one hour was made upon Vega with an „aperture of three centimeters, and the result was, of course, an impression on „the plate of the size and form of the aperture. Exposures were then made upon „the sky for equivalent lengths of time, with apertures ranging from 10 to 15 „centimeters. The result should be a nearly uniform darkening all over the plate, „which would receive light from an area of the sky the diameter of which would „depend upon the aperture used and the distance of the plate from the aperture. „If the darkening of one of these plates should be of the same intensity as the „impression made by the light of Vega, then we would have the very simple „relation, the light received from an area of the sky x degrees in diameter is „equal in actinic intensity to the light received from Vega. After a few experi-„ments it was seen that the time necessary to get a set of plates — about five „hours — could be greatly reduced and the effect of changing atmospheric „conditions avoided by making all the exposures on the sky at the same time. „This was accomplished by mounting four camera-boxes, simply aperture and „plate-holders, upon a polar axis made of a piece of wood 4 × 4 inches. In „the very limited length of time which I had to devote to this work it was „possible to obtain only a few sets of plates. The plates of each set were of „course developed at the same time in a large tray. In the exposures a portion „of each plate was left covered by the slide in order to measure the effect of any „chemical fog which might appear in the development."

In this way the galactic sky was found to be 1.9 times as bright as the non-galactic sky, and the light received from an area one degree in diameter equivalent to the light of a 4.5 magnitude star. The author believes that, though his provisional results are poor, a reliable method has been found.

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[1]) As to the first reason, it will afterwards be shown, that it is possible, that the brightness of the sky increases near the horizon, but there is much reason to doubt, whether it is perceptible without an excellent instrument. The changes of colour towards the horizon are very deceptive.

Prof. KAPTEYN, as is communicated in his „*Plan of selected Areas*", has occasionally performed some experiments by applying a visual method.

To show the principle of the instrument used a rough scetch is given in the accompanying figure. *AB* is a tube, partly conically widened. At *B* it is closed by a suitable ground opal glass *ab*. *L* is a small incandescent lamp, which can be moved in the tube, *cd* an opal glass plate and *mn* an iris-diaphragm.

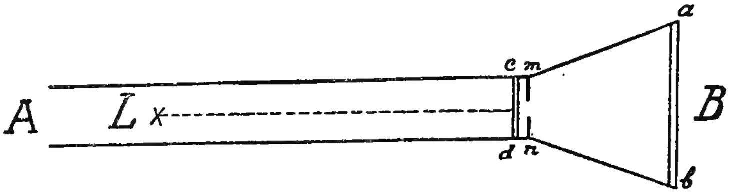

Fig. 1.

The illumination of the plate *ab* is altered by means of the iris-diaphragm until the brightness of *ab* appears to be equal to that of some portion of the sky. The brightness is measured by the diameter of the opening in the diaphragm. With this instrument some determinations have been made in our country and also in South-Africa at a greater altitude above the sea-level. The results were nearly equal to those obtained by other investigators. In South-Africa, however, the relative brightness of the Galaxy was found to be a little greater than in our country. On the whole the instrument did not answer the purpose. First the bounding line between the two comparison-fields could not be made sufficiently sharp and therefore it did not vanish at equal illumination. Secondly the comparisons were hindered by the slightest difference of colour between the illuminated glass plate and the sky.

I have purposely entered so much into the details of earlier investigations, 1^0 because in photometric work it is difficult to find out reliable methods, and 2^0 to justify the supposition that the question must be much more complicated, as the results differ widely from those obtained by star-gauges.

In the next chapter, I will pass on to the description of the methods and instruments used in the course of my own investigations.

CHAPTER II.

VISUAL DETERMINATIONS.

A. THE RELATIVE BRIGHTNESS OF THE SKY.

3. *Description of the instrument.*

While experimenting during his stay in South-Africa, Prof. **Kapteyn** devised the following method. An ordinary visiting-card, illuminated by a lamp, was held against the background of the sky. By a suitable variation of the illumination the card was first seen as a brighter spot against the darker skyground, then it vanished to appear afterwards as a darker spot against the brighter skyground. A provisional instrument, based on this principle, seemed to answer the purpose. For the present investigation we first proceeded to the construction of an improved photometer after the above-mentioned method. The instrument had to satisfy the following conditions:

1^0. It should be as simple as possible and easily transportable;

2^0. it should be adapted for measuring the brightness of every portion of the sky;

3^0. no tubes should be used in order to avoid reflection;

4^0. the field of uniform illumination should be as large as possible;

5^0. the observer's eye must be nearly 40 centimeters from the screen to avoid fatigue;

6^0. the source of light should stay continually behind the observer.

Of the methods, which may be used to vary the illumination of the screen in a measurable way, that of varying the distance of the light-source seemed to us the most reliable. Owing to the 5th and 6th condition its use, however, necessitates a rather long track over which the light-source must be movable. Provisional observations showed that its length should be at least 150 centimeters. At first we thought of making use of a straight tube or bar. The mechanicians, consulted, however, were incapable of furnishing a perfectly rectilinear bar of sufficient length, which at the same time would satisfy the first condition. We therefore attempted to vary the illumination in another way, but the experiments, which may be passed over here, did not succeed. Returning to the first idea, it occurred to us to move the lamp along strongly stretched steel-wires. This plan was carried out by Mr. D. A. Vonk, instrument-maker of the Physical Laboratory at Groningen, to whom we are greatly indebted for his help in overcoming mechanical difficulties.

The instrument is shown in the accompanying illustrations (Plate I and II). The main-tube (diam. 1.5 cm., length 170 cms) is an ordinary gas-pipe to the ends of which the iron-plates *cc* are attached. At the upper end this tube passes into a thinner one (diam. 1 cm., length 60 cms) Between the plates *cc* two steel wires *aa'* (diam. 1.4 mm.) are stretched one on each side of the tube and at a mutual distance of 5 cms. Along these wires slides the lampholder *M*. Nearly at the centre of gravity the tubes are supported by a side-arm with a screw-thread. The rectangular plate *oo*, which is connected with iron-wires *gg* to the plates *cc*, can be moved up and down this side-arm. By screwing the nut *ss* (Plate II) downward the wires *cc* are stretched and tend to bend down the main-tube, counteracting in this way the tendency to a bending the other way under the strain of the upper wires *aa'*. When the instrument is not used, the nut is moved upward and the tube is bent upward. Before observation, however, it is approximately straightened by a downward motion of the nut.

The lampholder *M* is carried by two little tubes (length 6 cms), fitting tight round the wires *aa'* The carriage is moved by drawing the silk string *ll'*, which runs over the pulleys *mm* and *nn*. The ends of the string are attached to the lampholder. The spring *d* serves to keep the string stretched.

At the end of the narrow tube the screen *Q* is mounted on a separate stand. The observer looks at the screen through the opening at *S*, nearly 10 cms to the left of the line joining the centre of the screen and the lamp. The whole can be turned about an horizontal axis *HH* and a vertical axis *G* [1]), and can easily be mounted on the stand *I*. As far as possible all parts of the photometer are coated with a dull black varnish. The main-tube is provided with a centimeter-scale.

With a provisional instrument some experiments were made to get the best form and size of the screen. Star-shaped and circular screens cannot serve the purpose: the limb and the centre do not vanish at the same time as may be easily understood. A flat ring, as shown on Plate I, is to be preferred. The size of the screen is not quite immaterial. Too small a one is troublesome and too large a one often does not wholly vanish, even in the non-galactic regions. Three screens of the following dimensions were prepared: *a* interior diam. 9 mms, exterior diam. 30 mms; *b* int. diam. 19 mms, ext. diam. 42.5 mms; *c* int. diam. 25 mms, ext. diam. 50 mms. Screen *c* was not used at all in the present observations. *b* is the most convenient and gives the most satisfactory results. The screens are made as follows:

A paste of fine grained white alabaster plaster being cast on a metal-plate of required form and size, is shaken a little to remove air-bubbles, then covered with a coarse-grained ground glass, and turned upside down. When the plaster is hardened, the screen can be easily taken away by tapping on the glass-plate. The inner and outer edges of the screen are scraped off with a knife to obtain the required form. Care should be taken, that no metal is uncovered at the edges, so that the screen is uniformly white up to the very edges. In this way excellent screens can be got.

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[1]) As the line of sight (*SQ*) does not coincide with the line joining the lamp and the centre of the screen, the portion at the zenith could not be observed with our photometer. It is therefore advisable to place the vertical axis above the horizontal.

As a moving object is more readily perceived than an object at rest, we originally intended to increase the sensitiveness of the photometer by a moving screen. The plan was given up, however, because the precision of the instrument is very satisfactory without such a device.

As stated before, the lampholder slides by means of tubes along the steel-wires. These tubes carry a rectangular table, at the centre of which a support is fastened. The case attached to the top contains an electric lamp (*f*). At *k* an opal glass, a suitable blue glass and a diaphragm can be inserted. The illuminated opal glass is the source of light. Its intensity can be varied to a certain extent by moving the lamp in the case. At *pp* the conducting-wires are attached. The lamp can be moved up and down by means of sliding tubes, which are clasped with the screw *q*.

In order to avoid vibrations the steel-wires *aa'* are *strongly* stretched and the lampholder is made as light as possible. The moving lamp can only slightly vibrate in a direction perpendicular to the axis of the instrument, but these vibrations do not perceptibly affect the results, because the lamp is always moved very slowly and the field of uniform illumination is a large one.

At the beginning the instrument was used in the form described above. The screen, however, was illuminated by the light of the sky itself as well as by the lamp. We had presumed, that the light of the sky at night would be too weak to have any perceptible influence. In measuring portions near the zenith this may be true, but for other portions of the sky an error is introduced, which increases with the zenithdistance. During some nights this error can be considerable. To shield the screen from the illumination of the sky, the box *TT* (Plate I) is put on the front-tube. It consists of a light iron-frame, partly covered with dull blackened cardboard. The bottom and the hind part are open. In the centre of the front part an opening is made so as not to cut off the light of the lamp from the screen. The smaller opening to the left is used to look at the screen. Afterwards, in order to make all the parts of the instrument as light as possible, the box was replaced by an aluminium cylinder (diam. 20 cms, length 40 cms). The dimensions are so chosen that no incident light can fall on the inner-side of the cylinder.

4. *Method of observing.*

When the photometer was mounted on the stand, the lamp was lighted, which was always done five or ten minutes before the beginning of the observation. The axis of the tube was put parallel to the steel-wires and the string was attached to the carriage of the lamp. The lamp and the screen were put at the same height above the tube. I have always taken it at 15 cms. The distance between the lamp and the tube should not be too small in order to prevent as much as possible the influence of reflection. The conducting-wires by their weight may cause a small inclination to the lampholder. To avoid this, the wires are taken as light as possible and bound up at *H* in such a way that just sufficient range of motion is left to the lamp. In making the observations, the observer takes the handle *P* in the right hand, draws the string with the left hand and looks with the right-eye through the small opening *S* at the screen. Care is to be taken, that no light is cut off from the screen by some part of the observer's head. The screen can be made to disappear against the sky by moving the lamp from front to back and in the opposite direction. The vanishing-points are noted and the mean of these two settings is considered as a complete observation.

The distance of the vanishing-points depends on the dimensions and the quality of the screen. The size giving the best results is easily found by experiment. More troublesome is the colour of the source of light.

When the photometric law of distances is used, the incandescent lamp is inconvenient as a *direct* source. An illuminated surface is to be preferred. Therefore, as already stated, a piece of opal glass is inserted before the lamp. It gives a somewhat yellowish tinge to the screen. The colour of the sky is a little variable. In the non-galactic regions it is at times dark-blue, at times more or less milk-white, even though the transparency of the air is the same. Towards the horizon the colour changes; as a rule in our country it is grayish at small altitudes. To make the mean colour of the sky and that of the screen agree, a piece of deep blue glass is inserted before the lamp. In this manner the brightness of the sky could always be measured. The slight differences in the colour of the sky have but little influence, which seems to be mainly due to the following causes: 1⁰ the intensity of the light of the sky is very small; 2⁰ irregularly reflected light and no direct light is used[1]). — After some experience the brightness of galactic as well as non-galactic regions can be easily measured. It is of high importance to observe, that it makes great difference, whether the eye is focussed on the screen or on the sky.

As in the Milky Way nearly uniformly illuminated patches are of little extent, I have, in measuring such regions, only made the inner edge of the screen to disappear. The outer- and the inner-limbs of the screen *b* are seen respectively under angles of 6 and 2.7 degrees. For certain portions of the Milky Way screens of a more suitable form may be used. Close to the horizon the upper and lower part of the annular screen do not vanish at the same time. For such altitudes a rectangular screen might be used to advantage having the shorter side perpendicular to the horizon.

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[1]) We have been much struck by the fact that the sensitiveness to small differences of colour is so much lessened by the use of a reflecting screen. We find that other observers have made the same remark.

In making the settings, it is very troublesome to have a bright star either in the opening of the screen or even at a small distance outside the outer limb. It is advisable to cover such stars by the screen. Sometimes this cannot be done in regions rich in lucid stars, but in nearly all cases I have succeeded by focussing the eye on the screen.

Finally it is to be observed, that our photometer is also peculiarly adapted for measuring the brightness of the Zodiacal- and Aurora-light. On March 26, 1908 I have determined the intensity of the Aurora-light.

5. *The observations.*

From August 1907--May 1908 observations were made at Borger, Holland (52° 56′ N. Lat., $26^{m}.5$ L. E. of Greenwich) a village, far away from towns with artificial light. The largest town in the neighbourhood is Groningen (about 75000 inhabitants) at a distance of nearly 36 KM. On clear nights the light of this town could not be perceived. Only when the sky was clouded, a streak of light was seen at the horizon. The lanterns of the village cannot have had any notable effect. The observations were made on clear nights when the sun was at least 18 degrees below the horizon and the moon not shining.

The foot of the instrument was mounted inside a blackened fence, built upon the flat roof of a house, which commanded an open view of the horizon in all directions.

At the beginning various portions at nearly the same zenith-distances or the same portions at different altitudes were measured both in the galactic and non-galactic regions. This method should have been the correct one, if the light of the sky was wholly due to telescopic stars. This not being the case, we have preferred to observe portions having nearly the same azimuth and different altitudes.

It would be very important, that different series of observations could be combined. It stands to reason that we should make use of standard portions just in the same manner as is done in a photometric Durchmusterung, but, as will appear afterwards, this way cannot be followed before the problem will be thoroughly investigated. I have only determined the brightness at the North Pole repeatedly on the same night.

I have given pretty close attention to the circumstances of the observation. Temperature and humidity of the air were several times recorded on every night of observation. The magnetic disturbances were kindly supplied by the Royal Dutch Meteorological Institute. I also wished to make observations on atmospheric electricity, but this proved to require too much time for one person In the daytime I have frequently tried to make observations on solar halos and cirri, but the results are poor on account of the unsteadiness of the weather in our country.

The number of suitable nights has been very small during the time of observation. A great number of the observations afterwards proved to be of little value, partly because a systematic error was introduced by the absence of the box above-described, partly because we have had no reliable absolute method at the beginning. Besides, in our latitude nearly all the regions above the horizon in autumn and early in winter are of lower galactic latitude; still we cannot attack the problem without thoroughly investigating the regions near the galactic pole. Therefore winter and early spring are the most favourable times of observation. Only the observations, made on March 25, 26, 31, and April 1, 29, were retained. They are given in Table 1 at the end of this paper.

The coordinates of the centres of the portions of the sky, the brightness of which has been determined, are estimated by means of the apparent position of the screen among the stars, *e. g.* half way α and β Aurigae Sometimes I made use of the dimensions of the screen, *e. g.* α Virginis = upper edge of the screen. In order to be able to compute the azimuth and the altitude the time of observation was recorded by means of an excellent watch, which was frequently compared with a railway-clock showing Greenwich-time. These methods, though somewhat rough, are sufficient for the purpose. The brightness of the same portion was generally determined three times, that is to say six settings were made at every turn Only on the night of April 29 two observations were made, because in our country the atmospherical conditions are so rapidly changing that it is difficult to get a rather long series of observations

The readings and notes were made by my wife, who has always faithfully assisted me in carrying out this work

The observations are communicated *in extenso* to give an idea of the reliability of the photometer. In the first five columns of table I are mentioned: the date of observation, the number, the siderial time of observation, the rectascension and the declination of the centre of the observed portion. In the 6th and 7th column the vanishing-points are given to the nearest half centimeter. *I* is got by moving the lamp from front to back, *II* by moving it in the opposite direction. The following columns contain: $r =$ the mean of I and II, $\log. \frac{1}{r^2}$, the mean $\log. \frac{1}{r^2}$ and the relative brightness, that is to say the brightness in terms of that of the comparison-portion (in heavy type).

In table 2 are given the determinations of the brightness at the North Pole on other dates. They contain a little systematic error due to the absence of the box, which was afterwards mounted on the photometer.

We wish to close this article with a few words about the sensitiveness of the instrument. Assuming, that the illuminating power of the incandescent lamp and the reflecting power of the screen have been constant for the observations on the same night, and that there are no systematic instrumental or personal errors, we have derived the probable error ϱ of a single observation, that is to say the probable error of $\log. \frac{1}{r^2}$. We give also the same quantity expressed in magnitudes.

From all the determinations of the brightness at the North Pole on Oct. 5, 12, Nov. 5, 1907 (Table 2) we find respectively:

Oct. 5 $\varrho = \pm 0.0093 = \pm 0^m.023$ (27 obs.)
" 12 $\varrho = \pm 0.0097 = \pm 0.024$ (24 obs.)
Nov. 5 $\varrho = \pm 0.0373 = \pm 0.093$ (30 obs.)

These p e. are not wholly due to accidental errors They are affected by the variation of the brightness of the sky during the night. I have also computed, therefore, the mean of the p e. (ϱ') of a single observation of each set of three determinations. They are:

Oct. 5 $\varrho' = \pm 0.0056 = \pm 0^m.014$ (9 sets)
„ 12 $\varrho' = \pm 0.0027 = \pm 0\ .007$ (8 „)
Nov. 5 $\varrho' = \pm 0.0062 = \pm 0\ .015$ (10 „).

The p.e. of these p.e. are:

$0.0021 = 0^m.005$
$0.0009 = 0\ .002$
$0.0019 = 0\ .005$.

In the same way the 34 sets of three observations, made on April 1, 1908, (Table 1) give:

the mean probable error $\varrho' = 0.0042 = 0^m.01$
the probable error of these p.e. $= 0.0016 = 0^m.004$.

B. DETERMINATION OF THE BRIGHTNESS OF THE SKY IN TERMS OF STAR-LIGHT.

6. *The method.*

To express the brightness of some portion of the sky in terms of the light of a star of a certain magnitude, it is necessary to pass from an illuminated point to an illuminated surface or from an illuminated surface to an illuminated point. As quoted in Chapter I, Prof. Newcomb has adopted the first method by spreading out the light of a star by means of a concave lens. It seems to us, that there are grave objections to this method. The reflection of light at the surface of the lens, the absorption by the glass, and the spherical aberration are factors, which are not within the immediate control of the observer. It is true, that Prof. Newcomb has improved his method by placing a convex lens between the eye and the second dark glass, but even then the best results carry with them an element of uncertainty. Only the brightest stars can be used. Besides, the comparison-fields, which probably differ in colour, are separated by a considerable distance.

We have therefore tried other methods. Our first idea was to compare the brightness of the sky and that of the moon's surface by means of our photometer. After some trials this method was abandoned, because we met with insuperable difficulties: 1^0 the difference between the brightness of the sky and that of the moon is very considerable; 2^0 the apparent surface of the moon is comparatively small; 3^0 the colour of the moonlight differs widely from that of the sky; 4^0 the light of the moon is not uniformly distributed over the surface. Moreover the magnitude of the moon has not yet been determined with sufficient accuracy.

We finally succeeded in passing from an illuminated surface to an illuminated point in the following way. An illuminated surface of determined dimensions, seen at a distance very great in comparison with these dimensions, appears to be an illuminated point, an artificial star. If a suitable colour is given to the light of the surface, the magnitude of the artificial star can be compared with those of real stars. The quantity of light, received at this great distance, can thus be expressed in terms of star-light. Close by, the artificial star is seen as a surface, the brightness of which can be compared with that of some portion of the sky.

Let the illuminated surface be a circular disk of the diameter A, and let

I = the *brightness* of some portion of the sky, *viz.* = the quantity of light pro square degree;
αI = the *brightness* of the illuminated disk;
R = the distance, at which the disk is observed as a star;
μ = the magnitude of the artificial star;
$\log. \delta = 0{,}4$ = log. of the light-ratio.

The total quantity of light received from a star of magnitude 1.0 (according to the Potsdam scale) being taken as unity, the total quantity of light received from the artificial star at the distance R is $\delta^{1-\mu}$. The angle subtended by its diameter A being

$$\frac{A}{R} \cdot 57^\circ{,}296$$

its apparent area will be

$$\frac{\pi}{4}\left(57{\cdot}296\,\frac{A}{R}\right)^2.$$

Therefore, the quantity of light αI, received pro square degree (a quantity, which is independent of the distance) will be

$$\frac{4}{\pi}\,\delta^{1-\mu}\left(\frac{R}{57{,}296\,A}\right)^2 \quad \text{or}$$

$$I = \frac{4}{\pi}\,\frac{\delta^{1-\mu}}{\alpha}\left(\frac{R}{57{,}296\,A}\right)^2 \quad \ldots\ldots\ldots\ldots \quad (1)$$

A, R, μ and α being determined, the probleem is solved.

7. *The application of the method.*

The front of the box *V*, made of cardboard, (Plate I) contains an opal glass, suitable blue glass and diaphragm ($A = 1.83$ centimeter). This window is illuminated by means of an electric lamp in the box. At night it was mounted on a large stand, fastened upon the flat roof of the house. In the garden below at a distance (R) of 53 Meters the disk appeared to be a star of nearly the fifth magnitude. It is to be noticed, that for the correct determination of the magnitude the artificial star must be placed among the stars, so that it may be projected on the same background. The black part of the front round about the disk has no influence, provided it is not too large. Besides, great care must be taken in selecting a piece of blue glass so that the artificial star may get the mean colour of the real stars.

The magnitude of the artificial star is determined by means of the Zöllner photometer belonging to the Astronomical Laboratory at Groningen, an instrument of the old type by Ausfeld of Gotha. The usual oil-lamp was replaced by an electric lamp, attached to the end of the photometer tube. As the instrument was not provided with a movable telescope tube, I used the accompanying telescope with very short focal distance and diaphragm so that the artificial and real stars could be focussed at the same time. In order to reduce the magnitude of the artificial star to some photometric system, the magnitudes of several stars of different brightness should be determined. The defective altazimuth mounting of the photometer compelled me to use only stars near the North Pole. I determined the magnitude of but two or three stars to save time in view of the rapidly changing atmospheric conditions. Systematical errors owing to the photometer are avoided in taking stars, which have on the average nearly the same magnitude as the artificial star. It would also have been desirable to estimate the magnitudes, but having no experience I did not do so [1]).

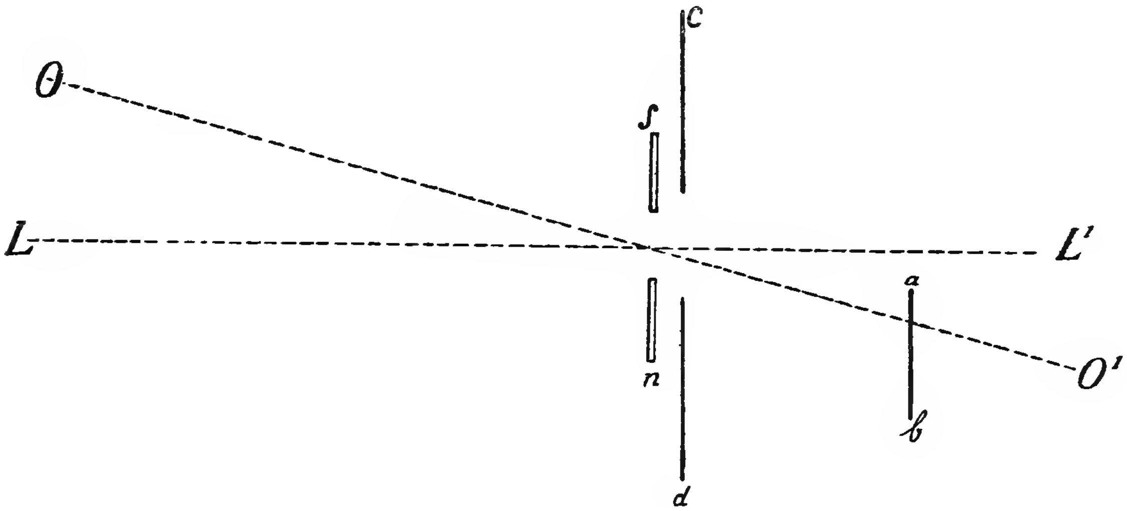

Fig. 2.

The comparison of the brightness of the disk and that of some portion of the sky is more difficult, because the difference is very great. Besides, in this investigation we have always to deal with the *brightness* or quantity of light, received from the unit of surface, whereas nearly all the photometrical methods are relative to the comparison of illuminated fields apart from the dimensions. We have tried and adopted the following method.

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[1]) Another and perhaps still more promising method to determine the magnitude photometrically is that of the reflecting spheres (cf. Müller, *Die Photometrie der Gestirne*, *p.* 226 *sqq.*).

The brightness of the disk is diminished by a neutral-tinted absorbing-glass of high power, made by Zeiss. In a suitable room the reduced brightness of the disk is compared with that of the illuminated screen of our photometer. The smaller screen *a* is used. The arrangement is illustrated by the accompanying figure 2. The lamp is movable in the direction LL^1 The observer looks in the direction OO^1 at the illuminated disk *ab* through the hole in the screen *sn*. *cd* is a dull blackened screen with an opening. Care is being taken, that no light of the lamp of the photometer can reach the disk *ab*. The measurements are made just in the same way as the determinations of the brightness of the sky. Immediately after the observation of the artificial star-disk the brightness of some portion of the sky (the comparison-portion) is measured with the same screen *a*. Then this screen *a* is replaced by the screen *b* and again the brightness of the same portion is measured.

A weak point of this method is the absorbing-glass. For it afterwards appeared that it causes a great deal of trouble to determine with sufficient precision the small coefficient of transmission of the dark glass. In order to avoid such a glass, we have constructed the apparatus, of which Plate III shows a longitudinal and transverse section. *A* and *B* are two cylindrical boxes (diam. 7 cms), open at the sides facing each other. The other ends have circular openings, *ab* and *fg*. In front of *A* a short tube is attached, in which an opal glass, blue glass and diaphragm may be inserted and kept in place by the ring *cd*. The tube at the hind part of *B* contains an opal glass before the opening *fg* and an electric lamp which can be moved in the tube and clasped by the screw *S*. Both boxes are carefully blackened on the inside, and are provided with diaphragms having in them the openings, *op* and *mn*. The sight-tubes at the top are put parallel to the axis of *A* and *B*. The two parts can be mounted on the bar *CD* or on separate stands by means of the rods *E* and *F*. At *H* the bar can be attached to a large stand at the top of a house or somewhere else. The use of the apparatus will be clear at once. Both parts, being mounted on the bar *CD*, are brought into contact. Box *A* sliding into *B* for about a centimeter, all exterior light is absolutely excluded and the opal glasses *ab* and *fg* are brought to a distance, which can be carefully determined once for all. The whole is attached to the stand on the roof. By means of the sight-tube the apparatus is directed towards the observer, who wishes to estimate the magnitude of the artificial star. After determining the magnitude, both parts are mounted on separate stands in a suitable room. Box *A* is put behind the screen of the photometer in the way shown in fig. 2. Box *B* is placed straight behind *A* at a sufficient distance so as to make the brightness roughly equal to the mean brightness of the screen of the photometer. The refined determinations are made with the photometer itself.

It will be remarked that by the use of this apparatus the whole of our measures, both relative and absolute, are now made to depend exclusively on the photometric principle of the inverse square of the distances.

Unfortunately the apparatus was only devised after the observations of the brightness of the sky had been closed.—Its use has been restricted therefore in the present case to the determination of the absorption of the neutral-tinted glass. In future it will be preferable, of course, to omit the absorbing-glass altogether.

8. *The observations.*

The distance R and the diameter A of the disk are kept constant for all the observations:

$$R = 5300 \text{ cms and } A = 1.83 \text{ cm.}$$

With these values, our formula (1) becomes, if we take logarithms,

$$\log. I = 4.9123 - \log. \alpha - 0.4\mu.$$

The error of the constant term cannot exceed 0.0080 or expressed in magnitudes 0.02. α and μ have to be determined for each series of observations separately.

Determination of μ.

The following comparison-stars have been used:

	Potsdam Dm. N⁰.	Potsdam Dm. Magn.	Harv. Annals Vol. XIV Magn.
I	574	4.42	4.46
II	13116	5.37	5.41
III	7632	4.94	5.06

The results of the photometric determinations, made with the Zöllner photometer, are given in Table 3. A. S. means the artificial star. Each star is observed in the four quadrants, so that each tabular value of φ_0 is the mean of four pointings. Log. $\sin^2 \varphi_0$ is denoted by l_0. This value corrected for extinction is represented by l. For these corrections the values given by Müller (*Die Photometrie der Gestirne*, *p.* 515—6) have been used.

Table 3.

Date 1908	A.S.			I			II			III		
	φ_0	l_0	mean	φ_0	l_0	l	φ_0	l_0	l	φ_0	l_0	l
March 25	11°.7	8.614	8.621	15°.2	8.837	8.862	9.9	8.471	8.497			
	11.9	8.629										
„ 26	11.6	8.607	8.607	14.9	8.820	8.845	10.0^5	8.484	8.510			
	11.6	8.607										
„ 30	11.7	8.614	8.614	15.2^5	8.840	8.865	9.9	8.471	8.497	11.1^5	8.573	8.584
„ 31	11.4	8.592	8.601	15.3^5	8.846	8.871	10.2^5	8.501	8.527	10.9	8.553	8.567
	11.6	8.607										
April 1	11.2^5	8.580	8.580	16.2	8.891	8.917	10.8^5	8.549	8.574	13.2	8.717	8.724

Taking the magnitudes of the comparison-stars from the Potsdam Durchmusterung, we have derived the values of table 4. μ is the mean of the values derived for the magnitude of the artificial star.

TABLE 4.

Date 1908	$l_I - l_{0A.S.}$	magn. A.S.	$l_{II} - l_{0A.S.}$	magn. A.S.	$l_{III} - l_{0A.S.}$	magn. A.S.	adopted μ
	m.	m.	m.	m.	m.	m.	m.
March 25	0.241 = 0.60	5.02	— 0.124 = — 0.31	5.06	. . . .	. .	5.04
„ 26	0.238 = 0.60	5.02	— 0.097 = — 0.24	5.13	. . . .	. .	5.07
„ 30	0.251 = 0.63	5.05	— 0.117 = — 0.29	5.08	— 0.030 = — 0.07	4.87	5.00
„ 31	0.270 = 0.67	5.09	— 0.074 = — 0.19	5.18	— 0.034 = — 0.08	4.86	5.04
April 1	0.337 = 0.84	5.26	— 0.006 = — 0.01	5.36	+ 0.144 = + 0.36	5.30	5.31
„ 29	. . . . .	. .	. . . .	. .	. . . .	. .	(5.04)

For each series of observations the corresponding value of μ has been used. On the night of April 29 the brightness of the stars could not be determined, the sky being suddenly clouded. We have assumed, that the value of μ on this night has been equal to the mean of the values of μ on March 25, 26, 30 and 31.

Determination of α.

If we denote the brightness of the disk by L and that of the comparison-portion of the sky by l, α is defined by the relation $\alpha = \frac{L}{l}$. The determination of this ratio has been carried out in three steps. First the brightness of the disk is diminished by a dark glass, transmitting the fraction p of the light. Secondly the reduced brightness of the disk pL is measured with our photometer. Thirdly the brightness of the comparison-portion l is determined in the same way. The distances of the lamp from the screen being respectively r_1 and r_2, we have

$$l = \frac{r_1^2}{r_2^2} \cdot pL$$

or

$$\alpha = \frac{r_2^2}{r_1^2} \cdot \frac{1}{p}.$$

The value of the coefficient of transmission p has been determined in different ways. The results are given in Table 5. Each value is the mean of several observations. Column I contains the results of the determinations made by means of the Lummer-Brodhun photometer. The values of column II are obtained in making use of the instrument shown on Plate III. The two parts A and B were mounted on the bar CD and brought into contact. The brightness of the disk in the front part of A, diminished by the absorbing-glass, was determined by means of our photometer (Plate I) in the way shown in fig. 2. Then the box B

was put straight behind *A* at a distance of nearly 180 cms. The dark glass being removed, the brightness of the disk was measured again with the photometer. The coefficient of transmission can be easily derived from the readings and the measured distances between the opal glasses of the apparatus. No two values of the table were obtained in exactly the same manner. After each determination the arrangement was more or less modified.

TABLE 5.

Log. of the coefficient of transmission p.

I	II
7.5150	7.5498
7.5371	7.5526
7.5420	7.5335
7.5364	7.5289
7.5100	7.5412
7.5129	7.5598
Mean 7.5256 ± 0.0039 (P. E.)	7.5443 ± 0.0033 (P. E.)

There is a small systematic difference of 0.0187 = 0.05 magnitude between the means of the two series, but as the separate values overlap, we took log. p to be equal to the mean 7.535 — 10.

The further measurements for the determination of α are contained in the following table.

TABLE 6.

Date 1908	Brightness of pL.					Brightness of the comparison-portion.							$\log.\frac{r_1^2}{r_2^2}$	$\log.\ a$
	Readings I	Readings II	r_1	$\log.\frac{1}{r_1^2}$	mean $\log.\frac{1}{r_1^2}$	Sid. time	Centre of the comparison-portion.	Readings I	Readings II	r_2	$\log.\frac{1}{r_2^2}$	mean $\log.\frac{1}{r_2^2}$		
						h m								
March 25	78.5	84.5	81.5	6.1777		12 7	North Pole	140.5	149.5	145.0	5.6777			
	79.5	84.5	82.0	6.1724				141.5	150.0	145.7	5.6731			
	81.5	82.5	82.0	6.1724				139.0	150.0	144.5	5.6803			
	82.5	80.5	81.5	6.1777				141.0	145.5	143.3	5.6875			
	78.5	82.5	80.5	6.1884				143.0	144.5	143.8	5.6845			
	80.5	82.5	81.5	6.1777	6.1777							5.6806	9.5029	2.9621
„ 26	80.5	84.5	82.5	6.1671		12 48	North Pole	119.0	122.2	120.6	5.8373			
	78.0	84.5	81.2	6.1809				120.5	120.5	120.5	5.8380			
	80.5	81.5	81.0	6.1835				119.0	126.0	122.5	5.8237			
	79.0	83.0	81.0	6.1835				121.5	124.5	123.0	5.8202			
	78.0	83.0	80.5	6.1884				120.5	122.0	121.2	5.8330			
	78.5	84.5	81.5	6.1777	6.1802							5.8304	9.6502	2.8148
„ 30	81.0	83.5	82.2	6.1703										
	78.5	85.5	82.0	6.1724										
	81.0	83.5	82.3	6.1692										
	81.5	81.5	81.5	6.1777										
	81.0	84.5	82.7	6.1650										
	80.5	80.5	80.5	6.1884	6.1738									
„ 31	80.5	82.0	81.3	6.1798		13 49	North Pole	98.5	106.5	102.5	5.9786			
	80.5	83.5	82.0	6.1724				102.0	105.0	103.5	5.9701			
	80.0	85.0	82.5	6.1671				100.0	103.0	101.5	5.9871			
	80.5	84.5	82.5	6.1671				100.5	108.5	104.5	5.9618			
	79.0	81.5	80.3	6.1906				99.0	107.0	103.0	5.9743			
	80.5	82.0	81.3	6.1798	6.1761							5.9744	9.7983	2.6667
April 1	79.5	82.5	81.0	6.1830		15 10	$\alpha = 11^h 26^m$ $\delta = +58^\circ.0$	100.5	100.5	100.5	5.9927			
	79.5	83.5	81.5	6.1777				102.5	104.5	103.5	5.9701			
	80.5	82.5	81.5	6.1777				101.5	105.5	103.5	5.9701			
	80.0	84.5	82.2	6.1703				102.5	101.5	102.0	5.9828			
	78.5	83.0	80.8	6.1852				102.5	102.5	102.5	5.9786			
	79.0	84.5	81.7	6.1756	6.1782							5.9795	9.8013	2.6637
„ 29	81.5	81.5	81.5	6.1777		15 17	North Pole	120.5	125.5	123.0	5.8202			
	80.5	82.5	81.5	6.1777				121.5	123.5	122.5	5.8237			
	79.0	82.5	80.8	6.1852				122.5	123.5	123.0	5.8202			
	82.5	82.5	82.5	6.1671				118.5	127.5	123.0	5.8202			
	81.5	81.5	81.5	6.1777				120.0	124.0	122.0	5.8273			
	82.5	84.0	83.2	6.1598	6.1742							5.8223	9.6481	2.8169

Table 6 contains the determinations of the relation between *I* and *pL*. It follows from the values of r_1, that the ratio of the illuminating power of the electric lamps has been constant during the time of observation. We have therefore assumed, that there has been no striking change of the illuminating power of each lamp separately. Small 2-volt lamps have been used. The current was supplied by accumulator cells, which were always treated with the utmost care.

The final results are given in table 7. We have taken as unit of brightness that of a star of magnitude 1.0 according to the Potsdam scale. As in Publ. 18 of the Astronomical Laboratory at Groningen the Harvard scale has been adopted, we have reduced our results to the same unit by means of the equation:

Potsd. Durchmusterung—Pick. I (Harvard Photometry) = $+ 0^m.16$

log. I refers to Potsdam scale, log. I' to Harvard scale.

TABLE 7.

Brightness of the comparison-portion.

Date 1908.	log. I.	log. I'	I'.
March 25	8.934	8.998	0.0995
26	9.069	9.133	0.136
31	9.219	9.283	0.192
April 1	9.124	9.188	0.154
29	9.079	9.143	0.139

With the aid of these data the relative brightnesses of Table 1 have been converted into absolute brightnesses (see Table 8 at the end of this paper).

CHAPTER III.

PHOTOGRAPHIC DETERMINATIONS.

9. *The method.*

To compare in a photographical way the brightness of various portions of the sky, equal portions of photographic plates are exposed to equal portions of the sky. For that purpose a number of tin boxes of the same form and size are made, having circular openings of the same diameter at the top and bottom. A plate-holder can be placed against the lower side by means of a second bottom. After exposing for a definite time, an impression is got of the size and form of the opening in the boxes. The intensity of the dark patches immediately gives the relative brightness. To get the brightness in terms of starlight, a plate is exposed to the light of a heavenly body for the same time and in the same manner. After measuring the intensity of the impression, the brightness can be expressed in terms of starlight.

As no two plates, taken from the same box, can *apriori* be said to be of the same degree of sensitiveness, all the exposures should be made on the same plate, but in view of the changing atmospheric conditions and the varying brightness of the sky they should also be made at the same time. As these two conditions cannot be fulfilled simultaneously and as the latter is probably the more important one, we have used a number of plates of the same emulsion.

There are two ways to make simultaneous exposures. As quoted above, TOWNLEY mounted the boxes on a polar axis. The axis of each box was directed for one hour to the *same* point of the sky. To get the brightness in terms of starlight, the axis of the Crocker telescope tube was pointed at a star for the same length of time. Consequently the zenithdistance was continuously varying. Though TOWNLEY does not mention it, it is impossible to reduce such observations without knowing the photographic absorption by the atmosphere. Now this correction is still very imperfectly known. Besides, it is rather considerable at small zenithdistances. For aught I know, the photographic extinction is only determined by SCHAEBERLE (*Contributions of the Lick Observatory*, *No.* 3) and PICKERING (*Annals of the Astr. Obs. of Harvard College*, *Vol* 19, *part II*, *p.* 247).

Moreover, Egon von Oppolzer afterwards raised grave objections to the results derived by Schaeberle from the observations. (*Die Photographische Extinction*, *Sitzungsber. der Akad. der Wiss. in Wien*, *Math.-Naturw. Classe*, *Bnd. CVII*, *Abth. II*, 1898).

Therefore I have tried the following method. A hemisphere made of iron hoops (diam. 1,6 M.) is mounted on a vertical foot AB (see Plate IV). The sphere can be turned about this stand and clamped at C. The boxes are attached to the hoops so that one box at the top points to the zenith and the axes of the others are directed *six and six* to points of the same zenith-distance [1]). During the time of exposure the apparatus stands still. Hence a certain portion of the sky passes each opening. The direction of the axes of the boxes is determined by looking along the edges. Though the boxes are accurately constructed and their edges practically parallel to the axis, this method is too rough a one. The illumination of the sky is too *faint* to look exactly along the edges of the *blackened* boxes. It would have been better to provide them with some suitable arrangement to fix the directions, but time did not allow us to make alterations.

The difficulty of the unknown photographical absorption is partly avoided by this method, because the centres of the observed portions have, *six and six*, the same altitude. The seeming advantage of Townley's method* that his instrument is continually directed to the *same* point of the sky, is more apparent than real. This will become manifest by the discussion of our results in Chapter IV. Even if at some future time the absorption will be better known, it will be no doubt preferable to let some portion of the sky pass the plates.

In order to express the brightness of the sky in terms of starlight, I have used the light of the moon. One of the boxes was directed to the full moon when near the meridian. The brightness of the light of the moon was diminished by an absorbing-glass, which at the same time cut off the light of the illuminated background of the sky. During the time of observation the plate continuously received the light from all the parts of the moon's surface There are, however, great objections to this method and we would not recommend it for future investigations, for 1^0 the magnitude of the moon is still insufficiently determined, 2^0 the difficulty of the unknown photographic extinction cannot be avoided, 3^0 it is very difficult — if not impossible — to determine *photographically* the absorbing-power of the glass with sufficient accuracy. I have tried various methods but I could not find a reliable one. The power of the glass depends on too many factors, which have not yet been sufficiently studied.

The method, adopted by Townley, seems to be more promising. He has exposed a plate to the light of a star. Because the darkening of the film is not only due to the light of the star, but also to the illumination of a small portion of the sky round about the star, it should be investigated, whether the effect of this portion, compared with that of the star, is practically insensible or that a correction must be applied.

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[1]) On plate IV are only three boxes, but we made use of more.

Summing up, I think the following method is the most promising. In order to determine the relative brightness of various portions of the sky, plates should be exposed in the same parallel of altitude, according to our method; to get the brightness of the sky in terms of starlight, a plate should be exposed — according to Townley's method — to the light of a star, when near the meridian and having nearly the same zenith-distance as the axes of the boxes used for the relative determinations.

10. *The observations.*

As the number of nights, suitable for photometric work, has been very small, and as I preferred to apply myself mainly to the visual determinations, I have made but two series of observations, one on Jan. 3 and the other on April 7, 1908. The apparatus, shown on plate IV, was damaged during the transmission so that it caused much trouble to make tolerable determinations.

As already stated, it is inconvenient to use the light of the moon to express the brightness in terms of starlight. Moreover, during the time of observation it happened but once, that the sky was sufficiently clear when the full moon was near the meridian. I have nevertheless resolved to give the results of the observations, as they stand. They may perhaps be useful to other investigators.

The degree of darkening of the plates depends on the kind of plate, the time of exposure and the angular aperture of the boxes. Of various kinds of plates we preferred the "Schleussner Ultra Rapid Platte". In view of the changing atmospheric conditions we thought it advisable to expose no longer than half an hour. Provisional experiments have shown that in our country the aperture of the boxes should then be at least 15 degrees to get a measurable degree of darkening. It is worth mentioning that Townley obtained a sufficient darkening after an exposure of one hour with an aperture of nearly 5.5 degree.

All the plates of the same series are treated by standdevelopment in a large tray. The plate exposed to the moon on April 16, 1908, was developed at the same time as the series of April 7, 1908. The observations of this date can therefore be expressed in terms of starlight, but those of Jan. 8 are only relative determinations. The results are given in Table 9 at the end of this paper. The co-ordinates of the measured areas are somewhat rough, but sufficient for the purpose. The degree of darkening of the various plates was measured by means of a Lummer-Brodhun photometer in the Physical Laboratory at Groningen.

According to the investigations of E. S King (*Annals of Harv. Coll. Obs. Vol XLI, N⁰. IX*: "*Absorption of photographic wedges.*") the absorption of a photographic film depends on the distance of the plate from the source of light, if this distance is not more than 5 cm. Therefore care has been taken that, in measuring the degree of darkening, all the plates are placed at the *same* distance, nearly 10 cm., from the source of light. Of course the differences between the transmission of the light by the darkened and undarkened portion of the film are measured. The mean aperture of the boxes is 15° 3′, which corresponds to an area of 177,6 square degrees. The apertures of the individual boxes deviate slightly from this mean aperture, but the amount of this deviation is 1,5 % at the most. Corrections were applied to reduce all the observations accurately to the mean aperture. The *logarithm of the coefficient of transmission* is given in the column headed "*Darkening*" (Table 9).

At a zenith-distance of 60°.4 the full moon, the brightness of which was diminished by the dark glass, gave the *darkening* 8.879. The absorbing-power of the dark glass is adopted to be 6,3 magnitude. As has already been stated, the illuminated background cannot have had any observable effect. According to MÜLLER (*Die Photometrie der Gestirne, p.* 340) 11,77 was taken for the magnitude of the full moon. In computing the absolute brightness we must know the photographic extinction. In accordance with E. VON OPPOLZER in his paper, quoted above, and SCHEINER, *Astron. Nachr. Vol* 124, *p.* 276, I assumed that this correction is double that for the visual magnitudes. For the visual extinction the values given by MÜLLER have been used. The photographical extinction at a zenithdistance of 60°.4 being found to be 0.47 magnitude in this way, the light really received by the plate is equivalent to that of a star of magnitude — 5.0. Hence the total light of $(2.512)^6$ stars of magnitude 1.0, spread out over a circle of a diameter 15° 3′, gives a *darkening* 8.879. Bij means of these data the absolute brightness given in column 10 of Table 9 has been computed.

The last two columns of this table are discussed in the next chapter.

CHAPTER IV.

DISCUSSION OF THE OBSERVATIONS.

11. *The relative brightness at the North Pole.*

All the determinations of the relative brightness at the North Pole are combined in Table 10 in four groups in such a way that for each group the illuminating power of the incandescent lamp may be considered practically constant. The mean brightness of each group has been taken as unity. In the table we have further added: the depression of the sun below the horizon, the temperature (degrees centigrade), the vapour-pressure (millimetres of mercury), the relative humidity (percent), the deviations of the magnetic declination D and the horizontal intensity H ($\gamma = 10^{-5}$ C. G. S-unit) from their normal values. The column "Remarks" contains observations on the general aspect of the sky.

From this table we draw the following conclusions:

1^0. *The general brightness of the sky, being measured by the relative brightness at the North Pole, is variable during the same night.*

This is obvious *e.g.* from the determinations of Nov. 4, 1907 (Group III).

2^0. *It is varying from night to night.*

Cf. the determinations of group I and also those of group IV.

On the night of Dec. 8, 1907, the sky was unusually bright. While experimenting we could easily make our readings and notes without the use of a reading lamp. At about three o'clock in the morning the landscape was lighted as in morning twilight or as by the half-moon. The brightest object in the sky was Jupiter. It was then that it struck me, that the illumination of the screen by the sky itself could by no means be neglected. Accidentally the sky had been very dark on all the preceding nights of observation.

3^0. *The air being equally transparent, the sky is brighter as it is less dark-coloured.*

On March 25, 26, 31, the differences of the absolute brightness of the comparison-stars (Table 3, p. 19) are relatively small. We assume therefore, that the transparency of the air has been the same on these three nights. At the same time the skybrightness is not at all the same. For, according to table 10 we have:

March 25: mean relative brightness = 0.67; colour: dark.
„ 26: „ „ „ = 0.90; „ : dark-blue.
„ 31: „ „ „ = 1.31; „ : pale-blue.

When the sky is palish-blue or milk-white, one feels inclined to suppose that the air is less transparent. On April 1, however, the sky was pale-blue and the air more transparent than on the preceding nights. It will not be difficult to find other similar instances.

4^0. *If the meteorological elements we have recorded, have any effect upon the general brightness of the sky, it is not very striking.*

The number of data, however, is much too small to draw reliable conclusions.

12. *The brightness of various portions of the sky.*

The mean brightness of different portions of the sky is given in table 8. The rotation numbers of the observed portions correspond with those of table 1 (the comparison-portions in heavy type). The following six colomns contain the galactic latitude b, the azimuth A, the zenith-distance z, the logarithms of the relative and absolute brightness, and the total light-quantity pro square degree, expressed in terms of the light of a star of magnitude 1.0 (H.S.).

If the supposition is correct, that the illumination of the sky is only due to the direct light of telescopic stars, the ratios of the total quantities of starlight at different galactic latitudes would be immediately derivable from the relative brightness, corrected for extinction by the atmosphere. To test this supposition, we have reduced the observations, made on April 1 and 29 (except the numbers 80—84)[1]. The results arranged in order of the galactic latitude are given in the following table:

TABLE 11.

April 1.						April 29.					
b	z	Relative brightness corrected for extinction	b	z	Rel. brightness c. f. e.	b	z	Rel. brightness c. f. e.	b	z	Rel. brightness c. f. e.
+ 3°	70.4°	2.11	57°	6.9°	0.701	+ 3°	76.1°	1.87	57°	19.7°	0.832
— 3^5	65.6	1.94	58	64.8	1.43	— 4	83.0	3.13	62	11.3	0.764
+ 7	65.1	1.82	61	37.7	0.818	+ 10	69.7	1 91	65	11.5	0.828
8	43.4	1.26	62	1.8	0.723	17	60.9	1.46	66	14.4	0.757
— 12^5	72.1	2.09	62^5	16.1	0.740	24	80.5^5	2.74	67	8.9	0.736
+ 24	69.0	1.75	66	25.0	0.771	27	37.0	1.17	67	36.4	0.929
26	63.3	1.43	70	50.8	1.04	27	37.0	1.08	67	29.4	0.906
27	37.0	0.889	70	35.3	0.891	27	37.0	1.00	69	30.2	0.879
27	37.0	0.929	72	19.1	0.755	28	49.1	1.12	72	12.5	0.745
27	37.0	0.859	76	44.6	0.959	29	75.7^5	2.04	75	50.5	1.11
45	74.6	2.03	78	18.4	0.731	38	65.5	1.58	77	25.8	0.910
50	69.4	1.74	79	31.7	0.804	39	38.5	0.964	83	38.6	0.975
51	47.8	0.982	82	37.7	0.867	48	54.2	1.24			
53	67.2	1.63	83	26.2	0.778	49	25.8	0.859			
57	61.7	1.37	83	26.1	0.828	56	44.8	1.05			

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[1] These observations are further rejected, because from 12^h 3^m to 14^h 58^m the general brightness of the sky was increased.

From this table it is apparent, that

1⁰. *the differences between the brightness of the galactic and non-galactic regions are astonishingly small;*

2⁰. *the relative brightness (corrected for extinction in the ordinary way) does not regularly increase towards the Milky Way.*

This surprising fact is clearly brought out by the above table. Still it is by no means so diverging from what we would expect, in *these* observations, which were taken in spring when the Milky Way is near the horizon, as it is in autumn observations.

Further observations, not communicated in the present paper, show that the brightness of the *same* portion of the sky *diminishes* with the zenith-distance. If the brightness of the background of the sky were only due to the light of telescopic stars, the brightness would of course be found to increase. The determinations N^os^. 61—69, made on April 1, are relative to portions with nearly the same azimuth and with a galactic latitude higher than 45 degrees. We know, therefore, that according to photometrical and statistical data the total amount of starlight must be almost the same[1]. Arranging the determinations in the order of the zenith-distances (Table 12), it appears that, *contrary to expectation, the observed brightness increases towards the horizon.*

TABLE 12.

z	*b*	Relative brightness.
1°.8	62°	0.745
18.4	78	0.748
26.2	83	0.787
37.7	82	0.851
44.6	76	0.914
50.8	70	0.953
61.7	57	1.11
69.4	50	1.21
74.6	45	1.17

From the facts, summed up in this and the preceding article, we infer:

The illumination of the background of the sky is not entirely due to the direct light of telescopic stars.

The very small differences in brightness between the galactic and non-galactic regions, and the increasing brightness towards the horizon justify the supposition, that there is some other source of light besides. In order to establish this fact beyond a doubt, relative determinations are insufficient. The brightness must be expressed in terms of starlight.

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[1] Comp. *Publ. Gron. Lab. No.* 18 *p.* 44.

In **No. 18** *of the Publ. of the Astr. Lab. at Groningen* (p. 44) Professor KAPTEYN has given an estimate of the total light of all the stars. For convenience' sake the results are communicated in table 13, columns 2, 3, 4.

TABLE 13.

TOTAL LIGHT OF ALL THE STARS PER SQUARE DEGREE.

Unit: light of a star, whose magnitude = 1.0 (H. S.).

b	A all the stars.	B stars $15^{m}.0$ and brighter.	$\frac{A}{B}$	C stars $5^{m}.5$ and brighter.	D = A—C.	E starlight per square degree.
0°	0.1864	0.0667	0.358	0.0054	0.1810	0.088
5	0.1612	0.0623	0.387	0.0053	0.1559	0.079
10	0.1183	0.0509	0.430	0.0050	0.1133	0.055
15	0.0788	0.0397	0.504	0.0046	0.0742	0.040
20	0.0550	0.0323	0.587	0.0043	0.0507	0.033
30	0.0318	0.0229	0.720	0.0037	0.0281	0.024
40	0.0222	0.0181	0.816	0.0032	0.0190	0.020
50	0.0178	0.0156	0.876	0.0029	0.0149	0.018
60	0.0151	0.0138	0.914	0.0026	0.0125	0.015
70	0.0135	0.0127	0.941	0.0025	0.0110	0.013^{5}
80	0.0126	0.0120	0.952	0.0024	0.0102	0.013
90	0.0122	0.0117	0.959	0.0022	0.0100	0.012

The author remarks about it: "Beyond the 15th magnitude the increase of "light corresponding to each successive further magnitude is excessively slow in "the higher latitudes. I have added in the third column the total light of all "the stars down to magnitude 15.0; in the fourth column has been set down the "fraction which this light is of the total light. Where this fraction is very high, "higher, say, than 0.80, I presume that our estimate of *the total light of all the* "*stars* must already be fairly correct. Admitting this, we see that, for all the "part of the sky having a latitude exceeding 40°, we may make a fair estimate "of the total light sent to us by the totality of the stars."

In the present investigation we have only to deal with the light of *telescopic* stars. The observer's eye being focussed on the screen and not on the sky, we have taken as telescopic all the stars fainter than magnitude 5.5. Perhaps this limit is still too low, that is to say brighter stars should be included, but it does not affect the results in any sensible way. Column 6 of table 13 contains the total light of all the stars fainter than magnitude 5.5, according to the data of Prof. KAPTEYN.

In the column, marked D, of table 8 the corresponding quantities 1), corrected for extinction, are given. Subtracting these numbers D from the observed total

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1) *Viz.* the total light of all the *telescopic* stars, according to column D of table 13.

quantities of light per square degree, which are expressed in terms of the same unit, we get the residuals Δ (table 8). In agreement with the lines quoted above we will now assume, that for portions with a galactic latitude higher than 45° the numbers D really represent the totality of the starlight. In this assumption the quantities of light Δ must necessarily be due to some other source of light. In table 8 these quantities for the higher galactic latitudes are printed in italics.

Comparing these Δ (for $b > 45°$) with the total amount of starlight D, we get as follows:

On March 25 : mean light due to unknown source = 7¼ × mean starlight.
„ „ 26 : „ „ „ „ „ „ = 9 „ „ .
„ „ 31 : „ „ „ „ „ „ = 15½ „ „ .
„ April 1 : „ „ „ „ „ „ = 12½ „ „ .
„ „ 29 : „ „ „ „ „ „ = 10 „ „ .

These figures seem wholly irreconcilable with the assumption that the light of the sky is equal to the total amount of starlight For it is evident that this assumption would require wholly inadmissable numbers of stars fainter than magnitude 15.0.

So we finally are led to conclude that the light of the sky is partly due to the direct light of telescopic stars, partly to some other source, which we shall term "*earthlight*".

Does this imply that the determinations of the brightness of the sky cease to have any astronomical value? We think not. For it must be evident that, with the necessary precautions, we must still be able to measure *the differences* in the total starlight of different portions of the sky, so for instance of the total starlight of equal areas in and near the Milky Way and near its poles. Such data must astronomically be considered of paramount importance.

From the residuals Δ furnished by portions with a galactic latitude exceeding 45°, we can form an idea about the distribution of the earthlight, or in other words about the brightness which the sky would show, if *direct* starlight did not exist. For the lower galactic latitudes this distribution will only be different on account of difference in zenith-distance and perhaps azimuth. The influence of these must be evaluated by direct experiments. Subtracting the earthlight thus computed from the apparent skybrightness, the remainder will be the total amount of starlight required, corrected for extinction by the atmosphere. The earthlight being a variable quantity as well as other meteorological elements, the individual results will show great differences. Means of long series of observations, however, must give a fairly correct idea about the apparent distribution of starlight.

This reduction is thus based upon the data given by Prof. Kapteyn for all the parts of the heavens, having a galactic latitude exceeding 45°. As these data for the magnitude 11.0 to 15.0 still rest on scanty materials, as the perfect rationality of the photometric scale is not beyond some doubt and as of course the extrapolation for the magnitude beyond 15.0 introduces an element of uncertainty, our results could not be given as thoroughly established, even though they rested on a sufficient number of observations of the skybrightness instead of resting on the small number of measures we succeeded in actually collecting.

Still, in our opinion, the determination that can be obtained of *the difference* between the total quantity of starlight in and near the Milky Way and that near the poles, must not be without its value. It is the only estimate of *this difference* which includes the stars fainter than the 15th magnitude, and it seems probable that it will give at least a fair idea about the *order* of its real amount.

For every date of observation apart all the residuals Δ have been plotted with the zenith-distances as abscissae. It was found in this way, that the residuals of portions with a galactic latitude within 45° were much smaller than those derived from the other portions. This means, of course, that the total light of all the stars for regions between $b = 0°$ and $b = 45°$ is given too large in *Publ.* **18**, *Astron. Lab. Gron.* A second feature of the plotted curves is, that the real residuals (for $b > 45°$) *increase* regularly from the zenith up to a zenith-distance of about 75 degrees. From this point on they show a decided decrease towards the horizon. All the observations of portions having a zenith-distance higher than 75° are however excluded from our final reduction, because they are but few in number and because in our country the horizon is generally far from clear.

We have tried to represent the residuals of March 25, 26, 31, which lie in a pretty straight line, by the empirical formula

$$A + Bz = \Delta,$$

those of April 1, 29, which evidently cannot be so well represented by a straight line, by the formula

$$A + Bz^2 = \Delta.$$

For the values of the constants we found:

March 25	A = 0.0771	B = 0.00023
„ 26	0.0762	0.00074
„ 31	0.1587	0.00056
April 1	0.1020	0.000014
„ 29	0.1018	0.000013

Comparison of the observed and computed Δ.

z	March 25		March 26		March 31		April 1		April 29	
	Mean O.—C.	Number of obs.	Mean O.—C.	Number	Mean O.—C.	Number	Mean O.—C.	Number	Mean O.—C.	Number
0°—30°	$+0.001$	5	-0.001^5	4	-0.006^5	2	0.000	8	-0.001	9
30 —50	-0.004	1	$+0.002$	4	$+0.010^5$	2	-0.002	6	$+0.001^5$	4
50 —70	-0.001	1	$+0.001$	3	-0.000^5	2	$+0.003$	6	$+0.002^5$	2

By means of these interpolation formulae the earthlight is computed for portions having a galactic latitude < 45°. These quantities are subtracted from the observed total light. After reduction of the remainder to the zenith by applying the corrections for extinction, we add the amount of light of the stars brighter than magnitude 5.5. In this way we obtain the following results:

b	Total light of all the stars.
2°.6	0.086
7 .7	0.067
13 .2	0.041
27 .0	0.026 ± 0.001 (P.E)
39 .3	0.019

From these values we have derived those of the column, marked E, of table 13 by means of a graphical interpolation. It is evident, that the differences of the individual results are relatively large. We could hardly expect that it would be otherwise. The number of observations too is very small. Still, in our opinion, the results must give some fairly correct idea of the total amount of starlight in the galactic regions.

It is to be observed that we have used a variable light-unit, *viz.* the brightness of a star of magnitude 1.0 (H S.), which changes with the state of the atmosphere. The residuals of different dates, therefore, are not immediately comparable. They might be easily reduced to the same light unit, but we have not thought it worth while to do so, because the number of observations is so small.

13. *Observations of the Aurora of March* 26, 1908.

As has already been stated, we had an opportunity to determine the brightness of the Aurora of March 26, 1908. After $8^h 45^m$ (sid. time) the sky near the northern horizon was coloured reddish as in the evening-twilight. From $12^h 55^m$ to $14^h 55^m$ streamers perpendicular to the horizon were observed, which had their azimuths between 130 and 235 degrees and reached an altitude of about 40 degrees.

We have made four determinations of brightness (*C.f.* the numbers 17^a, 17^b, 17^c, 30 of tables 1 and 8). By means of the data of the last column of table 13 the amount of earthlight (Δ) is computed. The actual residuals and those, which we should have probably obtained, if there had been no aurora, are the following:

Rotation number of the observation.	Earthlight + Aurora.	Earthlight.
17^a	0.255	0.131
17^b	0.270	0.131
17^c	0.293	0.131
30	0.273	0.133

As in the case of the light of the Milky Way (see p. 5), the ratio of the two series of numbers is much smaller than what could be expected from simple estimation.

14. *Earthlight.*

The illumination of the sky is caused partly by direct starlight, partly by some other source of light. The increase of the residuals Δ towards the horizon and the strong variations of the intensity of the skylight prove sufficiently, that we have to do with a terrestrial source. We have therefore termed "earthlight" that part of the skylight, which remains after subtraction of the total amount of starlight.

According to our observations this light is a constant feature of our nights; its amount, however, is subject to considerable fluctuations.

Several cases of abnormal light in moonless nights are on record. We will give a short account of those communicated by Dr. J. MAURER, Director of the Swiss Meteorological Institution at Zürich, in the *Meteorologische Zeitschrift*, *Vol. XVI* (1899), *p.* 257.

As early as 1788 HORACE BÉNÉDICT DE SAUSSURE mentioned in his "*Observations Météorologiques faites au col du Géant*" (*Mémoires Soc. phys. et d'hist. nat. de Genève*, *Vol. Suppl.* 1890, *No.* 9, *p.* 17) an observation of a pale, but clearly visible brightness all over the sky, gradually decreasing towards the zenith. A similar observation was made by ALEXANDER VON HUMBOLDT on the vulcano Antisana. *Cf.* also *Kosmos*, *Vol. I*, *p.* 146 *and p.* 207—8.

BESSEL also was acquainted with this phenomenon. On p. 89 of his "*Populäre Vorlesungen über wissenschaftliche Gegenstände*" (*Hamburg* 1848) he remarks: "Diese (Venus) giebt also zu gewissen Zeiten *eigenes* Licht von sich. Ist dieses "Licht etwa unsern Nordlichtern ähnlich? — *oder dem sehr hellen Glanze*, "*den wir auch in unseren Nächten zuweilen sehen*, *ohne angeben zu können*, "*woher es entsteht?*" [1])

Other authorities, quoted by the same author, are:

A. BURKHARDT: *Uebersichten der Witterung in Oesterreich und einigen auswärtigen Stationen.*

Prof. GALLE-BRESLAU: *Sirius*, *Vol. VI*, *p.* 103.

ADAM PAULSEN, Director of the Danish Meteorological Institution, in the "*Observations Iternationales Polaires* 1882—1883: *Expédition Danoise*, *Observations faites à Godthaab*," remarks on p. 9: "Durant mon séjour en Groënland j'ai souvent remarqué, même en l'absence de toute manifestation aurorale, "une clarté particulière apparaissant pendant la nuit, en plein hiver et à des "heures où l'influence du clair de lune était complètement écartée. Les nuits "étaient tellement pleines de cette clarté qu'on distinguait de petits détails à des "distances comparativement considérables. Ainsi l'observateur voyait distinctement, "sur une montagne distante environ 20 kilomètres, non seulement les endroits "couverts de neige, mais encore ceux où il n'y en avait pas. La lueur en question formait un contraste frappant avec les ténèbres de la nuit telles qu'on les "a sous de faibles latitudes."

JULIUS HANN, *Meteorologische Zeitschrift*, *Vol. XVI*, *p.* 23.

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[1]) We italicised the words important for the present subject.

AGASSIZ, *Geologische Alpenreisen*, *p.* 499, 645.

Further is mentioned, that XAVER ARNET has drawn attention to some interesting observations, made in Switzerland during the years 1895—99.

The results of all these observations may be briefly summed up as follows: When the sun is more than 18 degrees below the horizon, no moon shining and no auroral phenomena visible, it happens, that the sky, being *clear* or *overcast*, is *wholly* or *partly* illuminated. The brightness, which increases generally towards the horizon attains at times an intensity equal to the diffused light of the half-moon: printed letters of relatively small type are easily distinguished; watches can be read off very well; small objects are certainly visible at relatively large distances, *e. g.* telegraph-poles at a distance of 100 and more metres.

If on such nights the sky is clear, it is milk-white or pale-blue, and the course of the Milky Way is hardly perceptible.

On the other hand there are clear nights, which are so dark, that the outlines of trees are scarcely visible. If on such nights the sky is clouded, it is pitch dark [1]).

These results agree entirely with those obtained by myself and given in article 11. Moreover, we have repeatedly observed, that the brightness diminishes but little, when there came suddenly a dense fog. Even on the darkest night, when the sky was wholly covered with dark nimbi and not a single star visible, I have got a measurable impression on the photographic plate after an exposure of half an hour and at an aperture of 90 degrees.

What about the possible causes of earthlight?

It is sure, that it is partly due to diffused starlight. This can be inferred from the existence of diffused sunlight, but it is also apparent from the fact, that at times the sky in bluish-coloured. This can be ascertained best, when one half of the sky is covered with a sharply bounded cloud and the other half is clear. Then a remarkable difference in brightness as well as a decidedly blue colour can be observed.

As it is impossible to determine in a direct way the amount of diffused starlight, we must make use of the determinations of diffused sun- or moonlight. As far as I know, only Messrs. C. G. ABBOT, Director, and F. E. FOWLE, Aid of the Astrophysical Observatory of the Smithsonian Institution at Washington, have made accurate measurements about the ratio of direct sunlight and diffused skylight (*Annals of the Astroph. Obs. of the Smiths. Inst. Vol. II* (1908), *p.* 146—153; *Observations of the total solar eclipse of Jan.* 8, 1908, *Smiths. Misc. Coll.* 52, *Part. I*, *p.* 39, 44). From determinations, made on Flint Island (at sea-level) the following values, based on a sun-brightness of 10^7, are obtained:

Sun near zenith	10^7
Sky 20° from Sun	140
Sky distant from sun	31
Sky average.	62

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[1]) For further particulars we refer to the communication itself.

Measurements, made on Mount Wilson in California (altitude 1.800 metres) in 1905-6, showed that the average ratio of sunlight and diffused skylight, equal areas being measured, was about as 10^7 to 15, so that the sky at sea-level appears to be, roughly, four times as bright as on Mount Wilson.

From these data follows, that the total amount of diffused skylight per hemisphere is nearly 60 per cent of the direct sunlight (at sea-level).

We originally intended to make photographic determinations of the ratio of direct and diffused moonlight. We were, however, disappointed by the bad weather, as was the case with the rest of our work. Only on April 15, 16, 1908, some determinations were made.

The values obtained are:

	z Sky.	z Moon.	Ratio of brightness $\frac{\text{sky}}{\text{moon}}$.	Mean ratio.
April 15	0°.0	55°.2	344×10^{-8}	332×10^{-8}
	37.4		311	
	17.6		357	
	19.7		316	
April 16	0.0	60.4	303	282×10^{-8}
	17.3		284	
	18.4		277	
	18.1		262	

These results agree with those obtained by Messrs. Abbot and Fowle at sea-level (*Cf. Annals*, *Vol. II*).

According to the results, given in column E table 13, we get the total amount of starlight of the whole sky equivalent to

1350 stars of magnitude 1.0

or per hemisphere

675 stars of magnitude 1.0.

If we assume, that the stars are uniformly scattered over the heavens and that the diffused starlight is 60 per cent of the direct starlight, the average amount of diffused starlight pro square degree is nearly equal to 0.020 of the light of a star, whose magnitude = 1.0.

On the dates of observation the amount of earthlight (Δ) at the zenith was:

March 25	0.077
„ 26	0.076
„ 31	0.159
April 1	0.102
„ 29	0.102

We conclude therefore that a small part only of the earthlight can be explained by diffused starlight. There must be some other source besides.

Is there any reason to admit, that the illumination of the sky is partly effected by sunlight, reflected by the atmosphere? We always made our determinations, when the sun was more than 18 degrees below the horizon. It is, however, difficult to determine exactly the end and beginning of twilight, because we have to do with an imperceptible change, so that it is conceivable that a feeble twilight exists all night. If this is so, it must be shown by series of observations of the brightness at the North Pole, made during long winternights. The amount of earthlight should then regularly decrease with the increasing depression of the sun.

From our determinations follows, that the sun has had no perceptible influence. This result is in agreement with what is to be expected. If the sky was illuminated by reflected sunlight at a depression of more than 18 degrees, we should have to admit, that light is reflected by the atmosphere at a height of more than 80 kilometres. At the height of 80 K. M. JULIUS HANN (*Lehrbuch der Meteorologie* p. 9) estimates the barometric pressure at 0.00344, and at the height of 300 K. M at 35×10^{-7} millimetres of mercury. At these elevations the air is too rare and too pure to have any sensible reflecting power.

It is more probable that every night the sky is partly or wholly illuminated by a general aurora. ADAM PAULSEN remarks at p. 10 of the paper, quoted above: "Il n'est pas déraisonable d'admettre que cette clarté particulière est une "manifestation atténuée et paisible de la même cause, qui produit les aurores "boréales s'exerçant sur le ciel entier."

This supposition is strongly supported by the fact, that the spectrum of the skylight often shows the green Aurora-line ($\lambda = 557$), though no auroral phenomena are perceived. The following observations on this point have come to our notice.

ÅNGSTRÖM: "Ich fand sogar Spuren dieser Linie ($\lambda = 557$) während einer "sternhellen Nacht, wo der Himmel gewissermassen phosphoreszierte, "in dem Spektrum des von allen Teilen des Firmamentes ausgesandten "schwachen Lichtes." (After the translation by *von Schorlemmer* in *Roscoe-von Schorlemmer*: "*Die Spectralanalyse in einer Reihe von sechs Vorlesungen*," *Braunschweig* 1870, p. 180).

H. VOGEL, *Astronomische Nachrichten*, *Vol.* 79, 1872, p. 327—330:

"Die helle Linie ($\lambda = 557$) erschien übrigens an den genannten "Tagen an allen Theilen des Himmels, der mit einem matten, lichten "Schleier überzogen war, mehr oder weniger intensiv."

Prof W. W. CAMPBELL, *Astrophysical Journal*, *Vol.* 2, *p.* 162:

"It is possible to see the principal line in the aurora spectrum on "almost any dark clear night. I have looked for it in all parts of the sky "on at least a dozen occasions, always with success."

E. WIECHERT, *Physikalische Zeitschrift*, Vol. III, p. 366; *Meteorologische Zeitschrift* (1902) p 315:

"An den Tagen in der ersten Hälfte des Februar gelang es mir "nicht, die Polarlichtlinie mit einiger Sicherheit festzustellen, an sämmtlichen späteren Abenden aber trat sie mit grosser Intensität auf. Am "Osthimmel erschien sie fast ebenso hell oder gar heller als am Nord-"himmel und im S liess sie sich in einiger Höhe stets beobachten. Am

"28 Februar und am 3 März war sie mit Ausnahme eines kleinen Bereiches "in dem hellsten Lampenschein über dem mittleren Theile von Göttingen "am ganzen Firmament zu sehen, selbst im Zenith und am Horizont im S.

"Am 2 und eine Zeit lang am 3 März war der Himmel fast völlig "bedekt, die Polarlichtlinie zeigte sich dabei in allen Wolkenlücken und "hin und wieder sogar durch leichte Wolkenschleier hindurch. Am 3 März "konnte sie im kontinuirlichen Spektrum des hellen Nebels über dem "nördlichen Theile der Stadt bis zum Horizonte herab beobachtet werden.

"Das freie Auge sah in allen den beschriebenen Fällen nur eine ge-"ringe Erhellung des Himmels, welche diejenige der Milchstrasse in der "Regel durchaus nicht erreichte und nur einmal, am 3 März, vielleicht "in den ersten Abendstunden im N und E etwas übertraf. Die grösste "Helligkeit zeigte sich in 15—18° Höhe, in 45° Höhe war sie nur noch sehr "gering. Stets war die Erscheinung ganz diffus, ohne irgend welche "hervortretende Grenzen.

"Später ist es mehrfach gelungen, die Polarlichtlinie selbst bei Mond-"licht zu sehen. Aus den Beobachtungen ist zu schliessen, dass ein "merklicher Teil des nächtlichen Himmelslichtes in unseren Breiten auf "Rechnung von elektrischen Vorgängen in der Atmosphäre zu setzen ist."

15. *Conclusion.*

We have arrived at the following conclusions:

The light of the sky at night is composed of two parts, one reaching us directly from the stars, the other resulting from processes in the atmosphere.

The latter, termed "earthlight", is only partly due to the diffused starlight. It seems probable that the rest, wholly or in part, is due to a permanent aurora.

Photometric determinations, both visual and photographic, of the brightness of the sky are of great importance for astronomy as well as for meteorology. In both cases the aim of the investigation should be the distribution of earthlight over the heavens.

As to astronomy, the determinations may furnish data about the differences of the total amount of starlight received from the galactic and the extra-galatic regions. The way to reach this aim is described in article 12. The results are given in the last column of table 13.

Further investigations, which are highly desirable, should be made at the top of a high mountain, [1] where on several successive nights the sky is clear up to the horizon, the air very pure and consequently the variations of the brightness as small as possible. It is advisable to make the observations from the zenith towards the horizon in the same vertical-circles.

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[1] This summer Prof. ABBOT made some determinations of the skybrightness with our photometer on Mnt Whitney. The weather was extremely unfavourable, so that but a couple of observations could be made. Next year Prof ABBOT will probably be able to make more.

The observations made are the following:

As to meteorology, the determinations may probably provide us with some information about the general state of the atmosphere and so promote our knowledge of its upper layers. Measurements, made simultaneously at sea-level and at high altitudes, are desirable. At the same time observations should be made on other meteorological elements, terrestrial magnetism, atmospheric electricity, and last not least on the green aurora-line. Perhaps it is also possible to apply some spectrophotometric method.

Sept. 7, 1909. Mnt Whitney (altitude about 4500 metres).
Sky clear but damp. Circumstances not the normal ones for Mnt Whitney.

Sid time	Centre of the observed portion					Relative
	α	δ	b	A	z	brightness.
$21^h\ 9^m$	$18^h\ 36^m$	— 10° 0	— 4°	45°.4	58°.9	1.66
21 14	0 0	— 8.7	-- 69	310 7	59 7	1.05
21 17	15 40	+ 30 0	+ 51	112.1	68.4	1 00
21 19	13 40	+ 50.0	+ 64	217.0	76 1	1.21
21 19	18 36	— 10.0	— 4	47 7	60.3	1.66

From this determinations follows, that the ratio of the *apparent* brightness of the galactic and non-galactic regions is of the same order as the one we found in our country. A more accurate comparison shows, that the former is somewhat higher. Hence we may draw the inference, that the earthlight must be mainly due to processes in the upper layers of the atmosphere, which supports our hypothesis, that for the greater part the earthlight is due to a permanent aurora.

Relative brightness of different portions of the sky.

Date 1908.	No.	Sid. time.	Centre of the screen.		Readings.		r	$\log. \frac{1}{r^2}$	Mean $\log. \frac{1}{r^2}$	log. rel. brightness.
			a	δ	I	II				
		h m								
March 25	1	12 16	North	Pole	144·5	149·5	147·0	5·6654		
					145·0	150·5	147·8	5·6607		
					145·5	147·5	146·5	5·6683	5·6648	**0·0000**
			h m	°						
	2	12 25	12 12	+ 27·6	146·0	147·5	146·7	5·6671		
					144·5	149·0	146·7	5·6671		
					146·5	150·5	148·5	5·6565	5·6636	9·9988
	3	12 32	9 34	45·5	147·0	149·0	148·0	5·6595		
					146·0	150·5	148·2	5·6583		
					148·0	151·0	149·5	5·6507	5·6562	9·9914
	4	12 39	14 28	44·5	160·0	162·5	161·3	5·5847		
					159·5	165·5	162·5	5·5783		
					160·5	160·5	160·5	5·5890	5·5840	9·9192
	5	12 44	15 41	29·8	148·0	149·0	148·5	5·6565		
					148·0	151·0	149·5	5·6507		
					146·0	154·5	150·2	5·6467	5·6513	9·9865
	6	12 50	North	Pole	146·0	153·5	149·7	5·6496		
					146·0	148·5	147·3	5·6636		
					146·5	147·5	147·0	5·6654	5·6595	9·9947
			h m	°						
	7	12 59	5 31	+ 45·4	125·5	129·5	127·5	5·7890		
					126·0	130·5	128·2	5·7842		
					128·5	129·0	128·7	5·7808	5·7847	0·1199
	8	13 5	0 30	59·3	123·5	130·5	127·0	5·7924		
					125·0	128·5	126·8	5·7938		
					128·5	128·5	128·5	5·7822	5·7895	0·1247
	9	13 9	20 6	37·4	121·5	127·5	124·5	5·8097		
					122·0	123·5	122·8	5·8216		
					123·0	123·5	123·2	5·8188	5·8167	0·1519
	10	13 15	12 20	— 13·5	144·0	145·0	144·5	5·6803		
					143·0	145·5	144·3	5·6815		
					144·0	144·5	144·7	5·6791	5·6803	0·0155
	11	13 19	15 8	6·1	141·0	143·5	142·2	5·6942		
					142·0	144·0	143·0	5·6893		
					140·5	144·5	142·5	5·6924	5·6920	0·0272
	12	13 23	9 49	+ 5·8	140·5	144·0	142·2	5·6942		
					140·5	144·0	142·2	5·6942		
					138·5	147·0	142·7	5·6912	5·6932	0·0284
	13	13 27	12 12	28·0	144·5	149·5	147·0	5·6654		
					148·0	148·5	148·2	5·6583		
					144·5	149·5	147·0	5·6654	5·6630	9·9982
	14	13 31	12 31	26·9	148·0	149·0	148·5	5·6565		
					147·0	147·5	147·3	5·6636		
					147·5	147·0	147·2	5·6642	5·6614	9·9966

TABLE I.

Date 1908.	No.	Sid. time.	Centre of the screen.		Readings.		r	log. $\frac{1}{r^2}$	Mean log. $\frac{1}{r^2}$	log. rel. brightness.
			α	δ	I	II				
March 25	15	h m 13 35	North	Pole	142·0	147·0	144·5	5·6803		
					144·5	145·5	145·0	5·6773		
					144·5	146·0	145·2	5·6761	5·6779	0·0131
March 26	**16**	12 57	North	Pole	126·0	125·0	125·5	5·8027		
					120·5	126·5	123·5	5·8167		
					124·0	125·5	124·7	5·8083	5·8092	**0·0000**
	*17*a*	13 3	h m 2 52	° + 50·2	83·5	85·5	84·5	6·1463		0·3371
	*17*b*				80·0	85·0	82·5	6·1670		0·3578
	*17*c*				77·0	82·0	79·5	6·1993		0·3901
	18	13 6	15 41	29·8	136·0	140·5	138·2	5·7190		
					137·0	140·5	138·7	5·7158		
					137·0	140·5	138·8	5·7152	5·7167	9·9075
	19	13 10	16 46	63·8	137·0	137·5	137·2	5·7253		
					136·5	138·0	137·2	5·7253		
					134·5	138·5	136·5	5·7297	5·7268	9·9176
	20	13 14	12 16	23·5	130·5	135·0	132·7	5·7543		
					131·5	132·5	132·0	5·7587		
					131·5	131·0	131·2	5·7641	5·7590	9·9498
	21	13 19	10 28	44·4	133·0	142·0	137·5	5·7234		
					135·0	134·5	134·8	5·7406		
					138·0	135·5	136·7	5·7285	5·7308	9·9216
	22	13 25	North	Pole	126·5	130·5	128·5	5·7822		
					128·5	130·0	129·2	5·7775		
					129·5	130·5	130·0	5·7721	5·7773	9·9681
	23	13 27	h m 15 31	° + 75·1	138·5	142·5	140·5	5·7046		
					139·0	139·0	139·0	5·7140		
					137·5	143·0	140·3	5·7059	5·7082	9·8990
	24	13 35	1 3	70·8	111·5	111·5	111·5	5·9055		
					111·0	112·5	111·7	5·9039		
					109·5	113·5	111·5	5·9055	5·9050	0·0958
	25	13 39	1 46	60·2	100·5	98·5	99·5	6·0044		
					100·5	100·0	100·2	5·9983		
					101·5	98·5	100·0	6·0000	6·0009	0·1917
	26	13 47	13 31	29·2	140·5	144·5	142·5	5·6924		
					142·0	146·5	144·2	5·6821		
					142·5	147·5	145·0	5·6773	5·6839	9·8747
	27	13 50	13 50	9·8	131·5	131·5	131·5	5·7621		
					131·5	136·0	133·7	5·7477		
					132·5	136·0	134·2	5·7445	5·7514	9·9422
	28	13 55	13 4	— 1·9	124·5	129·5	127·0	5·7924		
					125·0	126·5	125·8	5·8006		
					128·0	128·0	128·0	5·7856	5·7929	9·9837

* Determination of the brightness of the Aurora.

TABLE I.

Date 1908.	No.	Sid. time.	Centre of the screen.		Readings.		r	log. $\frac{1}{r^2}$	Mean log. $\frac{1}{r^2}$	log. rel. brightness.
			α	δ	I	II				
		h m	h m	°						
March 26	29	14 0	12 52	− 13·3	127·5	128·5	128·0	5·7856		
					126·5	128·0	127·3	5·7903		
					128·0	126·5	127·3	5·7903	5·7887	9·9795
	*30	14 3	1 51	+ 50·1	79·5	88·5	84·0	6·1514	6·1514	0·3422
	31	14 7	16 29	39·7	143·5	142·5	143·0	5·6893		
					138·5	144·0	141·3	5·6997		
					142·5	144·0	143·2	5·6881	5·6924	9·8832
	32	14 12	17 44	31·9	126·5	131·5	129·0	5·7788		
					126·0	129·5	127·7	5·7876		
					126·0	127·5	126·8	5·7938	5·7867	9·9775
	33	14 16	18 54	16·0	114·5	116·0	115·2	5·8771		
					114·5	115·0	114·8	5·8801		
					114·5	116·0	115·3	5·8763	5·8778	0·0686
	34	14 20	11 28	57·7	137·5	140·5	139·0	5·7140		
					137·0	140·5	138·7	5·7158		
					138·0	139·0	138·5	5·7171	5·7156	9·9064
	35	14 23	9 34	45·5	128·5	132·5	130·5	5·7688		
					128·5	128·5	128·5	5·7822		
					129·0	130·5	129·5	5·7755	5·7755	9·9663
	36	14 28	8 50	31·3	121·5	121·5	121·5	5·8308		
					118·5	120·5	119·5	5·8453		
					118·5	125·5	122·0	5·8273	5·8345	0·0253
	37	14 33	North	Pole	125·5	128·5	127·0	5·7924		
					123·5	128·5	126·0	5·7993		
					124·5	130·5	127·5	5·7890	5·7936	9·9844
March 31	38	13 55	North	Pole	104·5	104·5	104·5	5·9618		
					105·5	104·5	105·0	5·9576		
					105·5	105·5	105·5	5·9535		
					105·5	105·5	105·5	5·9535		
					105·5	105·5	105·5	5·9535	5·9560	**0·0000**
			h m	°						
	39	14 49	11 28	+ 57·7	107·5	110·5	109·0	5·9251		
					110·5	111·5	111·0	5·9094		
					105·5	111·5	108·5	5·9291	5·9212	9·9652
	40	14 54	North	Pole	104·5	107·5	106·0	5·9494		
					105·5	106·5	106·0	5·9494	5·9494	9·9934
			h m	°						
	41	15 2	12 12	+ 24·0	102·5	105·5	104·0	5·9659		
					102·5	101·5	102·0	5·9828	5·9743	0·0183
	42	15 6	11 26	18·1	104·5	105·5	105·0	5·9576		
					103·5	106·5	105·0	5·9576	5·9576	0·0016
	43	15 8	14 0	19·3	103·5	101·5	102·5	5·9786		
					101·5	102·5	102·0	5·9828	5·9807	0·0247

* Determination of the brightness of the Aurora.

TABLE I.

Date 1908.	No.	Sid. time.	Centre of the screen.		Readings.		r	log. $\frac{1}{r^2}$	Mean log. $\frac{1}{r^2}$	log. rel. bright-ness.
			α	δ	I	II				
March 31	44	15 11	h m 15 41	° + 29·8	105·5 107·5	110·5 107·5	108·0 107·5	5·9332 5·9372	5·9352	9·9792
	45	15 14	North	Pole	100·5 102·5	103·5 104·5	102·0 103·5	5·9828 5·9701	5·9764	0·0204
	46	15 17	h m 0 30	° + 59·3	87·5 88·5	88·5 90·5	88·0 89·5	6·1110 6·0964	6·1037	0·1477
	47	15 26	17 41	54·0	107·5 106·5	106·5 110·0	107·0 108·2	5·9412 5·9315	5·9363	9·9803
	48	15 28	20 28	42·4	87·5 87·5	90·0 88·5	88·7 88·0	6·1042 6·1110	6·1076	0·1516
	49	15 31	9 34	45·5	104·5 103·5	103·5 102·5	104·0 103·0	5·9659 5·9743	5·9701	0·0141
April 1	50	9 58	North	Pole	107·5 108·5 108·5	114·5 115·5 113·5	111·0 112·0 111·0	5·9094 5·9016 5·9094	5·9068	9·9423
	51	10 3	h m 5 31	° + 45·4	93·5 94·0 95·5	95·5 94·0 96·0	94·5 94·0 95·7	6·0491 6·0537 6·0382	6·0470	0·0825
	52	10 8	5 31	6·8	89·5 88·5 89·0	91·5 91·0 92·5	90·5 89·7 90·7	6·0867 6·0944 6·0848	6·0886	0·1241
	53	10 14	7 7	− 5·5	88·5 86·5 88·0	89·0 86·5 86·5	88·7 86·5 87·3	6·1042 6·1260 6·1180	6·1161	0·1516
	54	10 19	9 11	14·5	93·5 93·5 95·0	93·5 94·0 95·0	93·5 93·7 95·0	6·0584 6·0565 6·0446	6·0532	0·0887
	55	10 23	12 31	8·5	97·5 94·5 94·0	95·5 95·0 96·0	96·5 94·8 95·0	6·0309 6·0464 6·0446	6·0406	0·0761
	56	10 30	14 41	+ 11·2	100·5 98·5 98·5	98·5 100·5 99·5	99·5 99·5 99·0	6·0044 6·0044 6·0087	6·0058	0·0413
	57	10 33	18 6	49·2	98·5 99·0 95·5	97·0 100·0 96·5	97·8 99·5 96·0	6·0193 6·0044 6·0355	6·0197	0·0552
	58	10 38	21 19	60·9	85·5 90·5 86·5	90·5 88·5 87·5	88·0 89·5 87·0	6·1110 6·0964 6·1210	6·1095	0·1450
	59	10 40	0 30	59·3	84·0 84·5 85·0	88·5 87·5 86·5	86·2 86·0 85·8	6·1290 6·1310 6·1330	6·1310	0·1665

TABLE I.

Date 1908	No.	Sid. time.	Centre of the screen.		Readings.		r	log. $\frac{1}{r^2}$	Mean log. $\frac{1}{r^2}$	log. rel. bright-ness.
			α	δ	I	II				
		h m								
April 1	60	10 46	North	Pole	106·5	111·5	109·0	5·9251		
					106·5	109·0	107·8	5·9348		
					108·5	111·5	110·0	5·9172	5·9257	9·9612
			h m	°						
	61	10 53	12 15	+ 31·2	114·5	119·5	117·0	5·8636		
					115·5	120·5	118·0	5·8562		
					116·5	118·0	117.3	5·8614	5·8604	9·8959
	62	10 57	12 35	20·3	114·5	111·5	113·0	5·8938		
					113·5	111·5	112·5	5·8977		
					112·0	114·5	113·2	5·8923	5·8946	9·9301
	63	11 1	12 52	14·2	109·0	108·5	108·7	5·9275		
					109·0	108·5	108·8	5·9267		
					108·5	110·5	109·5	5·9212	5·9251	9·9606
	64	11 3	13 3	8·3	110·5	105·5	108·0	5·9332		
					105·5	108·5	107·0	5·9412		
					106·5	104·0	105·3	5·9551	5·9432	9·9787
	65	11 8	13 17	— 2·6	97·0	100·5	98·7	6·0114		
					98·0	98·5	98·3	6·0149		
					99·5	98·5	99·0	6·0087	6·0117	0·0472
	66	11 11	13 31	9·7	93·5	94·5	94·0	6·0537		
					96·5	94·5	95·5	6·0400		
					96·0	94·5	95·2	6·0427	6·0455	0·0810
	67	11 16	13 40	14·9	96·5	97·5	97·0	6·0265		
					97·0	96·0	96·5	6·0309		
					94·5	96·5	95·5	6·0400	6·0325	0·0680
	68	11 23	12 2	+ 35·8	120·5	120·5	120·5	5·8380		
					120·5	119·5	120·0	5·8416		
					122·5	119·0	120·7	5·8366	5·8387	9·8742
	69	11 28	11 23	51·3	119·5	122·5	121·0	5·8344		
					120·5	122·5	121·5	5·8308		
					118·5	120·5	119·5	5·8453	5·8368	9·8723
	70	11 33	13 17	44·3	117·5	119·5	118·5	5·8526		
					117·5	119·5	118·5	5·8526		
					116·5	120·5	118·5	5·8526	5·8526	9·8881
	71	11 36	13 31	29·2	118·5	114·5	116·5	5·8673		
					117·5	114·5	116·0	5·8711		
					113·5	118·5	116·0	5·8711	5·8698	9·9053
	72	11 39	14 50	35·2	115·5	118·5	117·0	5·8636		
					118·5	117·5	118·0	5·8562		
					116·5	116·5	116·5	5·8873	5·8690	9·9045
	73	11 42	14 6	44·2	114·5	118·5	116·5	5·8673		
					118·5	118·5	118·5	5·8526		
					117·5	119·5	118·5	5·8526	5·8575	9·8930
	74	11 45	13 32	52·6	121·5	117·5	119·5	5·8453		
					119·5	121·5	120·5	5·8380		
					120·5	117·5	119·0	5·8489	5·8441	9·8796

TABLE I.

Date 1908.	No	Sid. time.	Centre of the screen.		Readings.		r	log. $\frac{1}{r^2}$	Mean log. $\frac{1}{r^2}$	log. rel. brightness.
			α	δ	I	II				
April 1	75	h m 11 48	h m 15 41	29°·8	110·5 108·5 108·5	108·5 109·5 106·5	109·5 109·0 107·5	5·9212 5·9251 5·9372	5·9278	9·9633
	76	11 50	12 11	27·1	111·5 112·5 113·5	111·5 113·5 113·5	111·5 113·0 113·5	5·9055 5·8938 5·8900	5·8964	9·9319
	77	11 53	11 26	18·1	112·5 110·5 109·5	110·5 110·5 111·5	111·5 110·5 110·5	5·9055 5·9133 5·9133	5·9107	9·9462
	78	11 58	North	Pole	110·5 111·5 113·5	114·5 115·5 114·5	112·5 113·5 114·0	5·8977 5·8900 5·8862	5·8913	9·9268
	79	12 3	h m 11 28	+ 57°·7	120·5 122·5 119·5	123·5 124·5 124·5	122·0 123·5 122·0	5·8273 5·8167 5·8273	5·8238	9·8593
	80	14 58	North	Pole	108·5 105·5 103·5 101·5	105·5 109·5 107·5 108·5	105·0 109·5 107·5 108·0	5·9412 5·9372 5·9535 5·9576	5·9474	9·9829
	81	15 18	h m 11 28	+ 57°·7	103·5 104·5 103·5	103·5 105·5 104·5	103·5 105·0 104·0	5·9700 5·9576 5·9659	5·9645	**0·0000**
	82	15 20	12 31	30·7	101·5 100·5 99·5	102·5 104·5 105·5	102·0 102·5 102·5	5·9828 5·9786 5·9786	5·9800	0·0155
	83	15 23	11 47	17·5	95·5 96·5 94·5	97·5 94·5 95·5	96·5 95·5 95·0	6·0309 6·0400 6·0446	6·0385	0·0740
	84	15 26	11 26	18·1	95·5 94·5 94·5	95·5 94·5 95·5	95·5 94·5 95·0	6·0400 6·0491 6·0446	6·0446	0·0801
April 29	85	13 40	North	Pole	115·5 113·5 112·5	115·5 116·5 118·5	115·5 115·0 115·5	5·8748 5·8786 5·8748	5·8761	0·0690
	86	13 49	h m 14 21	+ 42°·6	132·5 134·5	137·5 132·5	135·0 133·5	5·7393 5·7490	5·7441	9·9370
	87	13 52	15 7	38·2	133·5 130·5	137·5 136·5	135·5 133·5	5·7361 5·7490	5·7425	9·9354
	88	13 55	15 48	36·3	131·5 135·5	133·5 130·5	132·5 133·0	5·7556 5·7521	5·7540	9·9469
	89	14 0	16 32	26·7	125·5 125·5	128·5 130·5	127·0 128·0	5·7923 5·7856	5·7890	9·9819

TABLE I.

Date 1908.	No.	Sid. time.	Centre of the screen. α	δ	Readings. I	II	r	log. $\frac{1}{r^2}$	Mean log. $\frac{1}{r^2}$	log. rel. bright-ness.
		h m	h m	°						
April 29	90	14 2	17 11	19·7	119·5 119·5	122·5 123·5	121·0 121·5	5·8344 5·8308	5·8326	0·0255
	91	14 4	17 47	11·1	110·5 114·5	115·5 111·5	113·0 113·0	5·8938 5·8938	5·8938	0·0867
	92	14 6	18 5	3·2	108·5 107·5	107·5 109·5	108·0 108·5	5·9332 5·9291	5·9311	0·1240
	93	14 8	18 23	— 1·9	120·5 122·5	125·5 125·5	123·0 124·0	5·8202 5·8132	5·8167	0·0096
	94	14 10	18 46	6·7	128·5 124·5	124·5 127·5	126·5 126·0	5·7958 5·7993	5·7975	9·9904
	95	14 13	13 18	+ 44·3	138·5 141·5	142·5 143·5	140·5 142·5	5·7046 5·6924	5·6985	9·8914
	96	14 15	13 29	47·9	142·5 141·5	142·5 142·5	142·5 142·0	5·6924 5·6954	5·6939	9·8868
	97	14 17	14 24	38·6	138·5 140·5	142·5 140·5	140·5 140·5	5·7046 5·7046	5·7046	9·8975
	98	14 20	14 12	22·7	132·5 133·5	131·5 129·5	132·0 131·5	5·7589 5·7621	5·7605	9·9534
	99	14 22	14 11	16·6	131·5 128·5	128·5 128·5	130·0 128·5	5·7721 5·7822	5·7771	9·9700
	100	14 26	14 39	8·2	122·5 122·5	124·5 126·5	123·5 124·5	5·8167 5·8097	5·8132	0·0061
	101	14 29	14 48	— 1·1	117·5 117·5	116·5 119·5	117·0 118·5	5·8636 5·8526	5·8581	0·0510
	102	14 30	14 26	+ 23·6	128·5 129·5	131·5 129·5	130·0 129·5	5·7721 5·7755	5·7738	9·9667
	103	14 32	14 59	— 12·3	115·5 111·5	113·5 111·5	114·5 111·5	5·8824 5·9055	5·8939	0·0868
	104	14 35	15 8	22·5	118·5 116·5	118·5 115·5	118·5 116·0	5·8526 5·8711	5·8618	0·0547
	105	14 38	15 16	27·2	115·5 113·5 117·5	120·5 120·5 121·5	118·0 117·0 119·5	5·8562 5·8636 5·8453	5·8550	0·0479
	106	14 43	North	Pole	122·5 118·5 118·5	118·5 122·5 120·5	120·5 120·5 119·5	5·8380 5·8380 5·8453	5·8404	0·0333
			h m	°						
	107	14 47	13 32	+ 52·6	142·5 139·5	138·5 138·5	140·5 139·0	5·7046 5·7140	5·7093	9·9022
	108	14 54	12 41	40·3	129·5 130·5	127·5 128·5	128·5 129·5	5·7822 5·7755	5·7788	9·9717

TABLE I.

Date 1908.	No.	Sid. time.	Centre of the screen.		Readings.		r	log. $\frac{1}{r^2}$	Mean log. $\frac{1}{r^2}$	log. rel. bright-ness.
			α	δ	I	II				
		h m	h m	°						
April 29	109	14 56	12 12	28·7	127·5	126·5	127·0	5·7924		
					125·5	127·5	126·5	5·7958	5·7941	9·9870
	110	14 58	11 51	17·6	123·5	122·5	123·0	5·8202		
					123·5	121·5	122·5	5·8237	5·8220	0·0149
	111	15 13	North	Pole	125·5	125·5	125·5	5·8027		
					127·5	122·5	125·0	5·8062		
					123·5	126·5	125·0	5·8062		
					124·5	123·5	124·0	5·8132	5·8071	**0·0000**

TABLE 2.

RELATIVE BRIGHTNESS OF THE SKY AT THE NORTH POLE.

Date.	Sid. time.	Readings.		r	log. $\frac{1}{r^2}$	Mean log. $\frac{1}{r^2}$
		I	II			
	h m					
Sept. 9 1907	21 33	154.0	160.5	157.2	5.6071	
		152.5	161.0	156.7	5.6099	
		156.0	160.0	158.0	5.6027	
		158.0	163.5	160.7	5.5880	
		159.5	160.5	160.0	5.5918	5.5999
	23 8	163.5	157 5	160.5	5.5890	
		155.5	159.0	157.2	5.6071	
		158.5	160.0	159.2	5.5961	
		164.5	163.5	164.0	5.5703	
		161.5	159.0	160.2	5.5907	5.5906
	1 39	149.0	148.7	148.7	5.6554	
		147.0	143.0	145.0	5.6773	
		147.0	151.0	149.0	5.6536	5.6621
Sept. 10 1907	21 8	152.0	154.0	153.0	5.6306	
		149.0	152.0	150.5	5.6449	
		150.0	152.5	151.2	5.6408	
		149.0	152.5	150.7	5.6438	
		151.5	154.5	153.0	5.6306	5.6381
	23 15	149.0	152.5	150.7	5.6438	
		152.5	152.5	152.5	5.6335	
		146.5	152.5	149.5	5.6507	5.6427
	0 25	148.0	148.0	148.0	5.6595	
		146.0	149.0	147.5	5.6624	
		147.5	146.5	147.0	5.6654	
		149.5	150.0	149.7	5.6496	5.6592
	1 8	154.5	152.5	153.5	5.6278	
		155.5	149.0	152.2	5.6352	
		153.0	147.5	150.2	5.6467	5.6366
Sept. 11 1907	21 3	152.5	157.0	154.7	5.6210	
		158.0	156.5	157.2	5.6071	
		157.5	154.5	156.0	5.6138	5.6140
	22 32	157.5	153.0	155.2	5.6182	
		153.5	159.5	156.5	5.6110	
		153.5	157.5	155.5	5.6165	5.6152
	23 47	150.5	148.5	149.5	5.6507	
		147.0	151.5	149.2	5.6525	
		147.5	154.5	151.0	5.6420	5.6484
	1 43	151.0	148.5	149.7	5.6496	
		152.5	146.5	149.5	5.6507	
		148.0	150.5	149.2	5.6525	5.6509
Sept. 12 1907	21 7	147.0	148.5	147.7	5.6612	
		151.0	151.0	151.0	5.6420	
		149.5	146.5	148.0	5.6595	5.6542
Sept. 12 1907	23 39	145.5	139.5	142.5	5.6924	
		141.5	142.5	142.0	5.6954	
		144.5	142.0	143.2	5.6881	5.6920
	0 49	143.0	147.0	145.0	5.6773	
		138.5	146.0	142.2	5.6942	
		145.0	146.0	145.5	5.6743	5.6819
	2 21	146.0	140.5	143.2	5.6881	
		144.0	142.0	143.0	5.6893	
		141.5	140.5	141.0	5.7016	5.6930
Oct. 5 1907	22 13	154.5	154.0	154.2	5.6238	
		151.0	154.5	152.7	5.6323	
		152.0	151.5	151.7	5.6380	5.6314
	22 40	150.0	147.5	148.7	5.6554	
		152.5	148.5	150.5	5.6449	
		149.0	149.5	149.2	5.6525	5.6509
	23 6	146.0	149 5	147.7	5.6612	
		148.0	147.0	147.5	5.6624	
		148.0	149.5	148.7	5.6554	5.6597
	23 28	152.0	149.5	150.7	5.6438	
		152.5	150.5	151.5	5.6392	
		152.5	148.5	150.5	5.6449	5.6426
	23 50	157.0	152.5	154.7	5.6210	
		146.5	154.5	150.5	5.6449	
		150.0	150.0	150.0	5 6478	5.6379
	0 15	159.5	153.5	156.5	5.6110	
		154.5	154.5	154.5	5.6221	
		154.0	155.5	154.7	5.6210	5.6180
	0 44	153.5	153.5	153.5	5.6278	
		148.5	154.5	151.5	5.6392	
		149.0	153.0	151.0	5.6420	5.6363
	1 14	155.0	149.5	152.2	5.6352	
		148.5	148.5	148.5	5.6565	
		152.5	152.0	152.2	5.6352	5.6423
	1 57	154.0	155.5	154.7	5.6210	
		150.5	153.5	152.0	5.6363	
		151.5	147.5	149.5	5.6507	5.6360
Oct. 12 1907	0 44	156.5	151.5	154.0	5.6250	
		150.5	156.5	153.5	5.6278	
		150.5	155.5	153.0	5.6306	5.6278
	1 5	150.5	157.5	154.0	5.6250	
		152.0	160.0	156.0	5.6138	
		152.5	157.5	155.0	5.6193	5.6194

TABLE 2.

Date.	Sid. time.	Readings.		r	$\log. \frac{1}{r^2}$	Mean $\log. \frac{1}{r^2}$	Date.	Sid. time.	Readings.		r	$\log. \frac{1}{r^2}$	Mean $\log. \frac{1}{r^2}$
	h m	I	II					h m	I	II			
Oct. 12 1907	1 28	150·0	158·0	154·0	5·6250		Nov. 4 1907	0 20	126·0	132·0	129·0	5·7788	
		153·0	155·5	154·2	5·6238				121·0	131·5	126·2	5·7979	
		152·5	157·0	154·7	5·6210	5·6233			124·5	127·0	125·7	5·8013	5·7927
	1 58	154·5	157·5	156·0	5·6138			0 46	129·5	132·5	131·0	5·7655	
		156·5	158·5	157·5	5·6054				131·0	132·5	131·7	5·7608	
		156·5	156·5	156·5	5·6110	5·6101			130·0	130·0	130·0	5·7721	5·7661
	2 35	154·5	154·5	154·5	5·6221			1 25	125·0	128·5	126·7	5·7944	
		148·5	159·5	154·0	5·6250				128·5	126·0	127·2	5·7910	
		155·0	154·0	154·5	5·6221	5·6231			122·5	126·5	124·5	5·8097	5·7984
	3 7	151·5	151·5	151·5	5·6392			2 9	126·0	124·0	125·0	5·8062	
		155·0	152·5	153·7	5·6267				127·5	121·5	124·5	5·8097	
		151·5	156·0	153·7	5·6267	5·6309			128·0	125·5	126·7	5·7944	5·8034
	3 40	154·5	148·5	151·5	5·6392			3 53	120·5	114·5	117·5	5·8599	
		152·5	151·5	152·0	5·6363				119·5	118·5	119·0	5·8489	
		151·0	155.5	153·2	5·6295	5·6350			118·5	118·5	118·5	5·8526	5·8538
	4 11	147·5	151·5	149·5	5·6507			4 20	120·0	120·0	120·0	5·8416	
		151·5	148·0	149·7	5·6496				119·0	116·0	117·5	5·8599	
		151·0	150·5	150·7	5·6438	5·6480			116·0	116·0	116·0	5·8711	5·8575
Nov. 4 1907	23 41	121·5	123·5	122·5	5·8237			4 44	114·5	117·5	116·0	5·8711	
		119·0	120·0	119·5	5·8453				110·5	118·5	114·5	5·8824	
		119·5	123·5	121·5	5·8308	5·8333			110·5	114·0	112·2	5·9000	5·8845
	23 54	122·0	124·5	123·2	5·8188			5 30	100·5	110·5	105·5	5·9535	
		121·5	124·5	123·0	5·8202				103·5	103·5	103·5	5·9701	
		121·5	124·0	122·7	5·8223	5·8204			103·5	104·5	104·0	5·9659	5·9632

MEAN BRIGHTNESS OF DIFFERENT PORTIONS OF THE SKY.

No.	*b*	A	*z*	log. Rel. Br.	log. Abs. Br.	Abs. Br.	log. D.	log. D corrected for extinction.	Starlight D.	Earthlight *Δ*.
1	+ 27°	180°	37°·0	0·000	8·998	0·0995	8·518	8·498	0·0315	0·068
2	83	7	25·5	9·999	8·997	0·0993	8·004	7·997	0·0099	*0·089*
3	49	94	29·5	9·991	8·989	0·0975	8·182	8·171	0·0148	*0·083*
4	62	284	19·7	9·919	8·917	0·0826	8·084	8·081	0·0121	*0·071*
5	50	287	39·5	9·986	8·984	0·0964	8·173	8·150	0·0141	*0·082*
6	27	180	37·0	9·995	8·993	0·0984	8·518	8·498	0·0315	0·067
7	8	134	65·8	0·120	9·118	0·131	9·111	8·976	0·0946	0·036
8	-3^5	185	67·5	0·125	9·123	0·133	9·216	9·065	0·116	0·017
9	+ 1	236	68·5	0·152	9·150	0·141	9·247	9·085	0·122	0·019
10	48	14	67·5	0·016	9·014	0·103	8·192	8·041	0·0110	*0·092*
11	41^5	329	63·4	0·027	9·025	0·106	8·259	8·144	0·0139	0·092
12	43	63	64·0	0·028	9·026	0·106	8·242	8·123	0·0133	0·093
13	83	37	28·6	9·998	8·996	0·0991	8·004	7·994	0·0099	*0·089*
14	87	29	28·3	9·997	8·995	0·0989	8·001	7·992	0·0098	*0·089*
15	27	180	37·0	0·013	9·011	0·103	8·518	8·498	0·0315	0·071
16	27	180	37·0	0·000	9·133	0·136	8·518	8·498	0·0315	0·104
*17*a*	− 7	162	74·3	0·337	9·470	0·295	9·140	8·894	0·0783	0·217
*17*b*	− 7	162	74·3	0·358	9·491	0·310	9·140	8·894	0·0783	0·232
*17*c*	− 7	162	74·3	0·390	9·523	0·333	9·140	8·894	0·0783	0·255
18	+ 51	294	36·5	9·908	9·041	0·110	8·164	8·145	0·0140	*0·096*
19	37	227	29·3	9·918	9·051	0·112	8·318	8·308	0·0203	0·092
20	83	26	31·4	9·950	9·083	0·121	8·004	7·992	0·0098	*0·111*
21	59	90	29·0	9·922	9·055	0·114	8·104	8·094	0·0124	*0·102*
22	27	180	37·0	9·968	9·101	0·126	8·518	8·498	0·0315	0·094
23	37^5	198	25·3	9·899	9·032	0·108	8·310	8·303	0·0201	0·088
24	8	183	56·1	0·096	9·229	0·169	9·111	9·039	0·109	0·060
25	− 1	179	66·8	0·192	9·325	0·211	9·247	9·103	0·127	0·084
26	+ 79	9	23·9	9·875	9·008	0·102	8·010	8·004	0·0101	*0·092*
27	66	0	43·1	9·942	9·075	0·119	8·061	8·031	0·0107	*0·108*
28	60	15	55·9	9·984	9·117	0·131	8·097	8·026	0·0106	*0·120*
29	49	18	67·8	9·980	9·113	0·130	8·182	8·028	0·0107	*0·119*
*30	− 11	182	76·9	0·342	9·475	0·299	9·018	8·716	0·0520	0·247
31	$+41^5$	284	27·5	9·883	9·016	0·104	8·259	8·250	0·0178	0·086
32	25^5	278	43·1	9·978	9·111	0·129	8·557	8·527	0·0337	0·095
33	4	276	65·0	0·069	9·202	0·159	9·208	9·080	0·120	0·039
34	57	118	24·5	9·906	9·039	0·109	8·117	8·111	0·0129	*0·096*
35	49	111	45·8	9·966	9·099	0·126	8·182	8·145	0·0140	*0·112*
36	40	106	62·5	0·025	9·158	0·144	8·279	8·171	0·0148	0·129
37	27	180	37·0	9·984	9·117	0·131	8·518	8·498	0·0315	0·100
38	27	180	37·0	0·000	9·283	0·192	8·518	8·498	0·0315	0·161
39	57	120	28·3	9·965	9·248	0·177	8·117	8·108	0·0128	*0·164*
40	27	180	37·0	9·993	9·276	0·189	8·518	8·498	0·0315	0·158
41	82	65	43·1	0·018	9·301	0·200	8·005	7·975	0·0094	*0·191*
42	70	72	54·9	0·002	9·285	0·193	8·041	7·975	0·0094	*0·184*
43	70	28	36·2	0·025	9·308	0·203	8·041	8·023	0·0105	*0·192*
44	51	344	23·8	9·979	9·262	0·183	8·164	8·158	0·0144	*0·169*
45	27	180	37·0	0·020	9·303	0·201	8·518	8·498	0·0315	0·169
46	-3^5	202	62·8	0·148	9·431	0·270	9·216	9·106	0·128	0·142
47	+ 31	253	19·9	9·980	9·263	0·183	8·429	8·425	0·0266	0·157
48	1	250	49·2	0·152	9·435	0·272	9·247	9·202	0·159	0·113
49	49	121	54·7	0·014	9·297	0·198	8·182	8·117	0·0131	*0·185*

* Determinations of the brightness of the Aurora.

TABLE 8.

No.	*b*	A	*z*	log. Rel. Br.	log. Abs. Br.	Abs. Br.	log. D.	log. D corrected for extinction.	Starlight D.	Earthlight *Δ*.
50	+ 27°	180°	37·0°	9·942	9·130	0·135	8·518	8·498	0·0315	0·103
51	8	109	43·4	0·083	9·271	0·187	9·111	9·080	0·120	0·067
52	-12^{5}	77	72·1	0·124	9·312	0·205	8·962	8·753	0·0566	0·148
53	+ 3	50	70·4	0·152	9·340	0·219	9·224	9·039	0·109	0·110
54	24	18	69·0	0·089	9·277	0·189	8·594	8·426	0·0267	0·162
55	53	325	67·2	0·076	9·264	0·184	8·147	7·999	0·0100	*0·174*
56	58	286	64·8	0·041	9·229	0·169	8·110	7·984	0·0096	*0·159*
57	26	222	63·3	0·055	9·243	0·175	8·544	8·430	0·0269	0·148
58	7	190	65·1	0·145	9·333	0·215	9·140	9·012	0·103	0·112
59	-3^{5}	165	65·6	0·167	9·355	0·226	9·216	9·083	0·121	0·105
60	+ 27	180	37·0	9·961	9·149	0·141	8·518	8·498	0·0315	0·109
61	83	318	26·2	9·896	9·084	0·121	8·004	7·996	0·0099	*0·111*
62	82	321	37·7	9·930	9·118	0·131	8·005	7·984	0·0096	*0·121*
63	76	320	44·6	9·961	9·149	0·141	8·018	7·984	0·0096	*0·131*
64	70	320	50·8	9·979	9·167	0·147	8·041	7·990	0·0098	*0·137*
65	57	323	61·7	0·047	9·235	0·172	8·117	8·014	0·0103	*0·162*
66	50	323	69·4	0·081	9·269	0·186	8·173	8·001	0·0100	*0·176*
67	45	324	74·6	0·068	9·256	0·180	8·220	7·968	0·0093	*0·171*
68	78	334	18·4	9·874	9·062	0·115	8·013	8·010	0·0102	*0·105*
69	62	25	1·8	9·872	9 060	0·115	8·084	8·084	0·0121	*0·103*
70	72	286	19·1	9·888	9·076	0·119	8·032	8·029	0·0107	*0·108*
71	79	307	31·7	9·905	9·093	0·124	8·010	7·997	0·0099	*0·114*
72	61	278	37·7	9·905	9·093	0·124	8·090	8·069	0·0117	*0·112*
73	66	276	25·0	9·893	9·081	0·121	8·061	8·054	0·0113	*0·110*
74	62^{5}	260	16·1	9·880	9·068	0·117	8·081	8·079	0·0120	*0·105*
75	51	275	47·8	9·963	9·151	0·142	8·164	8·122	0·0132	*0·129*
76	83	349	26·1	9·923	9·111	0·129	8·004	7·996	0·0099	*0·119*
77	70	11	35·3	9·946	9·134	0·136	8·041	8·024	0·0106	*0·125*
78	27	180	37·0	9·927	9·115	0·130	8·518	8·498	0·0315	0·099
79	57	138	6·9	9·859	9·047	0·111	8·117	8·117	0·0131	*0·098*
80	27	180	37·0	9·983	9·171	0·148	8·518	8·498	0·0315	0·116
81	57	122	32·1	0·000	9·188	0·154	8·117	8·104	0·0127	*0·141*
82	86	71	37·7	0·016	9·204	0·160	8·002	7·981	0·0096	*0·150*
83	74	71	54·7	0·074	9·262	0·183	8·024	7·959	0·0091	*0·174*
84	70	77	57·7	0·080	9·268	0·185	8·041	7·962	0·0092	*0·176*
85	27	180	37·0	0·069	9·212	0·163	8·518	8·498	0·0315	0·131
86	65	329	11·5	9·937	9·080	0·120	8·066	8·065	0·0116	*0·108*
87	57	311	19·7	9·935	9·078	0·120	8·117	8·113	0·0130	*0·107*
88	49	299	25·8	9·947	9·090	0·123	8·182	8·175	0·0150	*0·108*
89	39	298	38·5	9·982	9·125	0·133	8·290	8·268	0·0185	0·115
90	28	294	49·1	0·026	9·169	0·148	8·496	8·451	0·0282	0·120
91	17	292	60·9	0·087	9·230	0·170	8·798	8·700	0·0501	0·120
92	10	293	69·7	0·124	9·267	0·185	9·054	8·878	0·0755	0·109
93	3	293	76·1	0·010	9·153	0·142	9·224	8·941	0·0873	0·055
94	− 4	291	83·0	9·990	9·133	0·136	9·208	8·682	0·0481	0·088
95	+ 72	52	12·5	9·891	9·034	0·108	8·032	8·031	0·0107	*0·097*
96	67	60	8·9	9·887	9·030	0·107	8·055	8·055	0·0114	*0·096*
97	66	354	14·4	9·898	9·041	0·110	8·061	8·060	0·0115	*0·099*
98	69	4	30·2	9·953	9·096	0·125	8·045	8·034	0·0108	*0·114*
99	67	5	36·4	9·970	9·113	0·130	8·055	8·037	0·0109	*0·119*
100	56	355	44·8	0·006	9·149	0·141	8·124	8·090	0·0123	*0·129*
101	48	354	54·2	0·051	9·194	0·156	8·192	8·129	0·0135	*0·143*
102	67	2	29·4	9·967	9·110	0·129	8·055	8·045	0·0111	*0·118*
103	38	353	65·5	0·087	9·230	0·170	8·303	8·171	0·0148	0·155
104	29	352	$75·7^{5}$	0·055	9·198	0·158	8·474	8·199	0·0158	0·142
105	24	351	$80·5^{5}$	0·048	9·191	0·155	8·594	8·184	0·0153	0·140
106	27	180	37·0	0·033	9·176	0·150	8·518	8·498	0·0315	0·118
107	62	96	11·3	9·902	9·045	0·111	8·084	8·083	0·0121	*0·099*
108	77	74	25·8	9·972	9·115	0·130	8·014	8·007	0·0102	*0·120*
109	83	68	38·6	9·987	9·130	0·135	8·004	8·982	0·0096	*0·125*
110	75	64	50·5	0·015	9·158	0·144	8·021	8·971	0·0094	*0·135*
111	27	180	37·0	0·000	9·143	0·139	8·518	8·498	0·0315	0·108

PHOTOGRAPHICAL DETERMINATIONS OF THE BRIGHTNESS OF THE SKY.

Date 1908.	No.	Sid. time of exposure.	Co-ordinates of the observed portions.		z	Mean b	Darkening.	Relative brightness.	Absolute brightness.	Starlight D.	Earthlight Δ.
			α	δ							
				First Set.							
			h h	°	°	°					
Jan. 2	1	4^h12^m—4^h42^m	4·2— 4·7	+53	0	+ 4	0·337	1·03			
	2		2·5— 3·0	46	mean 19·2	— 11	0·382	1·15			
	3		3·7— 4·2	34		13	0·388	1·16			
	4		5·3— 5·8	37^5		+ 3^5	0·390	1·17			
	5		6·3— 6·8	52		20	0·322	1·00			
	6		5·8— 6·3	69		22	0·306	0·96			
	7		2·1— 2·6	65		4^5	0·312	$0·97^5$			
				Second Set.							
	8	8^h8^m—8^h38^m	8·1— 8·6	53	0	36^5	0·268	0·88			
	9		6·3— 6·8	46^5	mean 19·8	18	0·337	1·03			
	10		7·5— 8·0	34		27	0·342	1·04			
	11		9·5—10·0	37		52	0·268	0·88			
	12		10·2—10·7	55^5		53	0·275	$0·89^5$			
	13		8·8— 9·3	72^5		36	0·266	0·88			
	14		5·9— 6·4	62		20	0·284	0·91			
	15		5·1— 5·6	32	mean 37·7	— 1	0·401	1·20			
	16		7·4— 7·9	16^5		+ 20^5	0·335	1·03			
	17		9·9—10·4	22		55	0·285	0·92			
	18		12·1—12·6	47		69	0·251	0·85			
	19		14·4—14·9	82		34	0·270	$0·88^5$			
	20		3·3— 3·8	63		7	0·321	$0·99^5$			
April 7	21	15^h47^m—16^h17^m	15·8—16·3	52	0	45^5	0·034	0·98	0·116	0·020	*0·096*
	22		14·6—15·1	39	mean 18·5	60^5	0·028	0·97	0·114	0·015	*0·099*
	23		16·2—16·7	35		42	0·029	0·97	0·114	0·022	0·092
	24		17·6—18·1	48^5		28	0·040	0·99	0·117	0·036	0·081
	25		17·5—18·0	65		30^5	0·037	0·99	0·116	0·031	0·085
	26		14·2—14·7	68		46	0·042	1·00	0·118	0·019	*0·099*
	27		13·7—14·2	50		63	0·036	0·99	0·116	0·015	*0·101*
	28		14·3—14·8	19	mean 37·5	63	0·040	0·99	0·117	0·014	*0·103*
	29		16·6—17·1	17		32	0·044	1·00	0·118	0·027	0·091
	30		19·0—19·5	37		10	0·096	1·13	0·133	0·108	0·025
	31		20·8—21·3	68		14	0·054	1·03	0·121	0·068	0·053
	32		10·3—10·8	68		45	0·039	0·99	0·117	0·018	*0·099*
	33		12·2—12·7	42		74^5	0·025	0·96	0·113	0·012	*0·101*

TABLE 10.

Mean relative brightness at the North Pole.

Date.	Sid. time.	Log. $\frac{1}{r^2}$	Log. relative brightness.	Relative brightness.	Depression of the sun below the horizon.	Temperature.	Vapour-pressure.	Relative humidity.	Deviation „Declination".	Deviation „Horizontal Intensity".	REMARKS.
					Group I.						
1907	h m				°	°			′	γ	
Sept. 9	21 33	5·5999	9·955	0·90	28·1	+ 9·1	7·55	87·7	0	0	Clear sky. Background: at first dark-blue, but towards the horizon pale-bluish and at the horizon grayish. After 0^h the colour of the sky changes till at is milk-white as at the beginning of morning-twilight.
	23 8	5·5906	9·946	0·88	31·5	8·0	6·63	83·0	0	0	
	1 39	5·2621	0·017	1·04	23·6	6·7	6·33	86·7	2	15	
Sept. 10	21 8	5·6381	9·993	0·98	26·3	8·0	7·31	91·5	5	3	Very clear sky. Fine weather. Background: dark-blue, towards the horizon pale-bluish.
	23 15	5·6427	9·998	0·99^5	31·9	7·4	7·00	91·3	6	63	
	0 25	5·6592	0·014	1·03	30·0	7·2	6·90	91·0	3	29	
	1 8	5·6366	9·992	0·98	27·1	7·0	6·91	92·5	4	8	
Sept. 11	21 3	5·6140	9·969	0·93	25·7	10·2	8·05	86·9	4	18	Sky as on Sept. 10. Background: at first as on Sept. 10, then at 23^h the Northern sky becomes milk-white.
	22 32	5·6152	9·970	0·93	31·6	9·4	7·37	83·9	4	5	
	23 47	5·6484	0·003	1·01	32·0	9·0	7·38	86·3	2	16	
	1 43	5·6509	0·006	1·01	24·5	8·0	7·19	90·0	5	0	
Sept. 12	21 7	5·6542	0·009	1·02	26·3	13·0	9·57	85·9	3	3	Clear sky, but the air is less transparent, somewhat hazy. Background: somewhat grayish.
	23 39	5·6920	0·047	1·11	32·6	11·7	9·10	88·9	0	0	
	0 49	5·6819	0·037	1·09	29·7	10·2	8·66	93·5	2	20	
	2 21	5·6930	0·048	1·12	21·5	9·6	8·54	96·0	0	9	
					Group II.						
Oct. 5	22 13	5·6314	9·997	0·99	32·8	10·2	8·55	92·3	0	0	Sky: at the beginning clear, then somewhat hazy. Background: pale-blue.
	22 40	5·6509	0·017	1·04	35·5	11·2	8·54	86·3	0	0	
	23 6	5·6597	0·026	1·06	37·7	10·0	8·18	89·5	3	28	
	23 28	5·6426	0·009	1·02	39·3	8·4	7·75	94·4	3	17	
	23 50	5·6379	0·004	1·01	40·5	9·7	8·13	90·7	2	7	
	0 15	5·6180	9·984	0·96	41·3	8·7	7·69	91·8	2	3	
	0 44	5·6363	0·002	1·00	41·6	7·2	6·90	91·2	2	0	
	1 14	5·6423	0·008	1·02	41·2	6·9	7·08	95·4	0	0	
	1 57	5·6360	0·002	1·00	39·3	6·6	7·05	97·1	0	0	
Oct. 12	0 44	5·6278	9·994	0·99	44·0	9·1	7·56	87·8	0	0	Sky and background as on Oct. 5.
	1 5	5·6194	9·985	0·97	44·3	8·8	7·40	87·8	0	2	
	1 28	5·6233	9·989	0·97^5	44·1	7·8	7·10	90·1	0	0	
	1 58	5·6101	9·976	0·95	43·2	7·6	7·00	90·0	0	0	
	2 35	5·6231	9·989	0·97^5	41·0	8·2	6·97	86·0	0	0	
	3 7	5·6309	9·997	0·99	38·3	7·7	6·94	88·6	0	22	
	3 40	5·6350	0·001	1·00	34·9	7·4	6·78	88·4	3	19	
	4 11	5·6480	0·014	1·03	31·2	6·7	6·55	89·6	2	0	

TABLE 10.

Date.	Sid. time.	Log. $\frac{1}{r^2}$	Log. relative brightness.	Relative brightness.	Depression of the sun below the horizon.	Temperature.	Vapour-pressure.	Relative humidity.	Deviation „Declination”	Deviation „Horizontal Intensity”.	REMARKS.
Group III.											
1907	h m				°	°			′	γ	
Nov. 4	23 41	5·8333	9·996	0·99	39·2	+ 2·6	4·04	73·5	3	0	Sky: at the beginning pretty clear, then somewhat hazy; near the horizon clouded. Background: at first dark-blue, then more and more pale-bluish, in the end speckled. The Milky Way seems to have no boundaries.
	23 54	5·8204	9·983	0·96	40·8	2·2	4·19	78·3	5	0	
	0 20	5·7927	9·956	0·90	43·8	1·8	4·14	79·6	3	12	
	0 46	5·7661	9·929	0·85	46·5	1·6	4·17	81·4	3	8	
	1 25	5·7984	9·961	0·91	49·8	1·1	4·09	82·8	0	7	
	2 9	5·8034	9·966	$0{\cdot}92^5$	51·9	0·7	4·15	86·5	0	0	
	3 53	5·8538	0·017	1·04	49·4	0·1	4·19	91·1	0	4	
	4 20	5·8575	0·020	1·05	47·1	— 0·1	4·48	98·0	0	5	
	4 44	5·8845	0·048	1·12	44·7	0·3	4·33	100·0	0	5	
	5 30	5·9632	0·126	1·34	39·2	0·6	4·07	100·0	0	6	
Group IV.											
1908											
March 25	12 16	5·6648	9·824	0·67	35·1	— 0·4	2·57	55·2	3	0	Clear sky. Fine weather. Background: dark.
	12 50	5·6595	9·818	0·66	34·7	1·2	2·49	59·6	2	0	
	13 35	5·6779	9·837	0·69	32·8	1·4	2·52	61·1	2	0	
March 26	12 57	5·8092	9·968	0·93	34·3	+ 0·2	2·92	63·1	4	48	Sky as on March 25. Background: dark-blue. Aurora.
	13 25	5·7773	9·936	0·86	32·9	— 0·5	2·79	63·1	17	96	
	14 33	5·7936	9·953	0·90	28·3	— 1·0	3·91	92·0	10	36	
March 31	13 55	5·9560	0·115	1·30	30·6	+ 2·1	3·63	68·4	0	3	Cumuli. Sky very clear between the clouds. Background: pale-blue.
	14 54	5·9494	0·108	1·28	26·2	. . . .	. . .	. . .	0	0	
	15 14	5·9764	0·135	1·36	24·2	. . . .	. . .	. . .	0	0	
April 1	9 58	5·9068	0·066	1·16	22·8	+ 0·6	3·23	67·7	3	10	Clear sky. Suddenly clouded at 15^h. Background: palish-blue.
	10 46	5·9257	0·085	1·22	27·4	0·6	3·22	67·5	6	6	
	11 58	5·8913	0·050	1·12	31·6	0·0	3·12	68·3	3	6	
	14 58	5·9474	0·106	1·28	25·7	— 1·4	2·77	67·2	2	6	
April 29	13 40	5·8761	0·035	1·08	21·8	+ 2·6	4·05	73·6	3	8	Very clear sky. Fine weather. Suddenly clouded at 15^h30^m. Background: somewhat palish-blue; towards the horizon milk-white, though not less transparent. The Northern coal-sack at 60° zenith-distance very certainly visible.
	14 43	5·8404	9·999	1·00	22·4	2·6	4·14	75·3	3	4	
	15 13	5·8071	9·966	$0{\cdot}92^5$	21·8				2	3	

PLATE I.

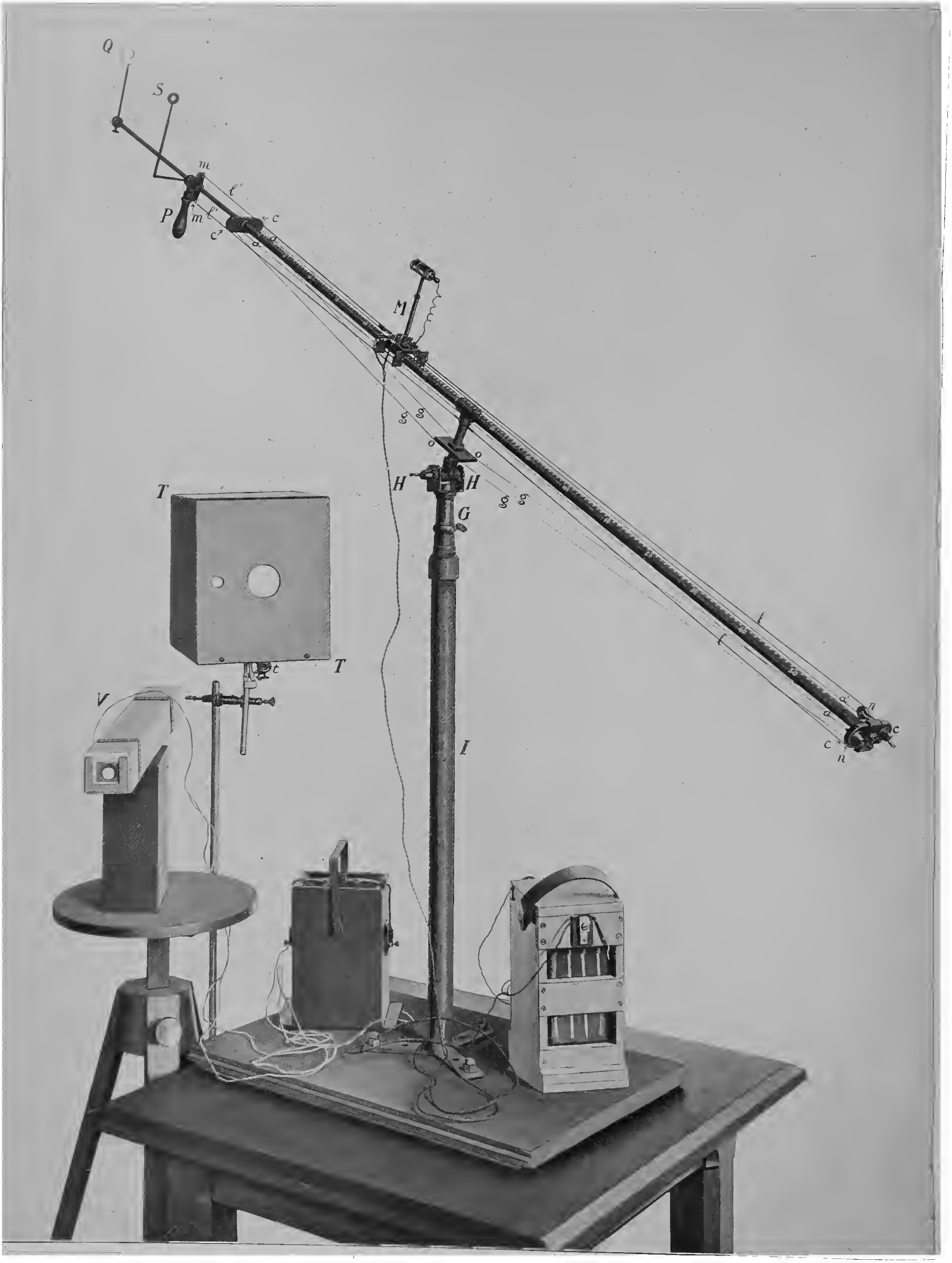


PLATE II.

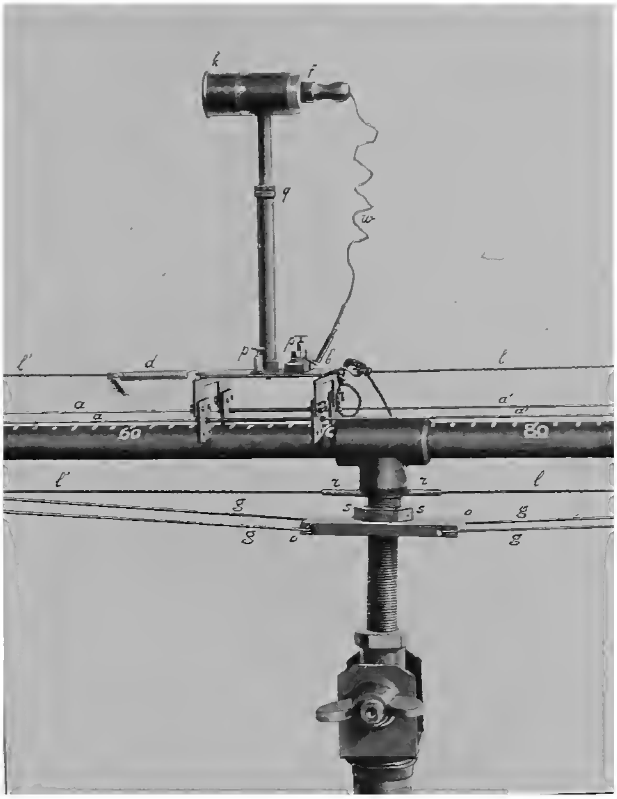


PLATE III.

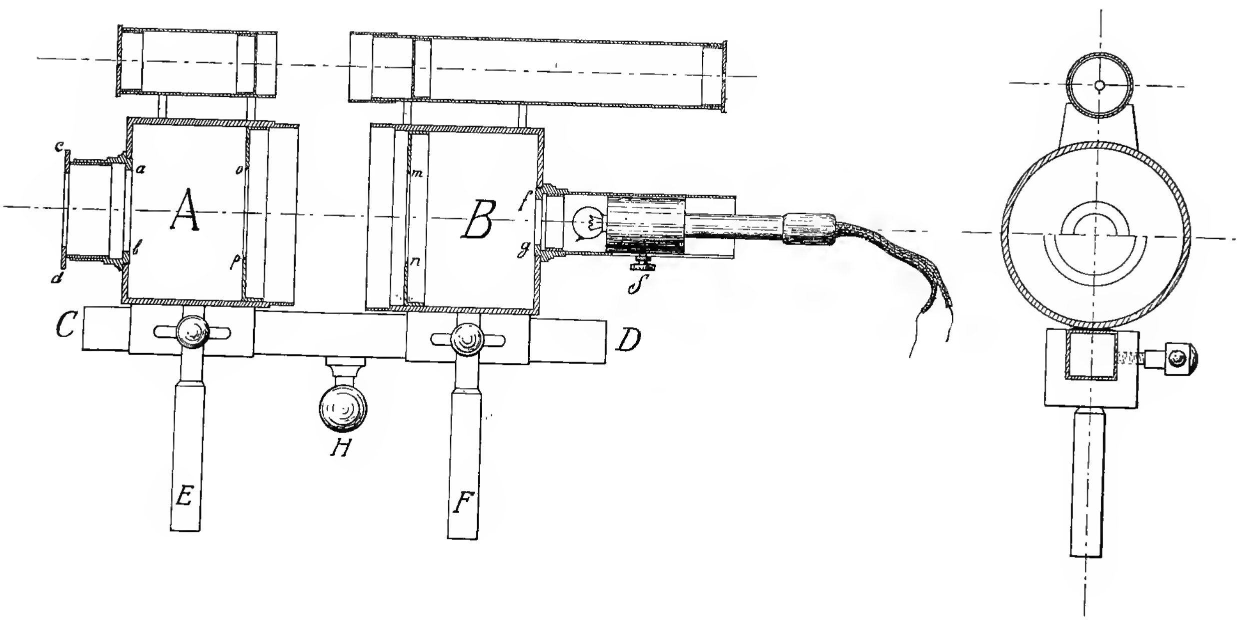
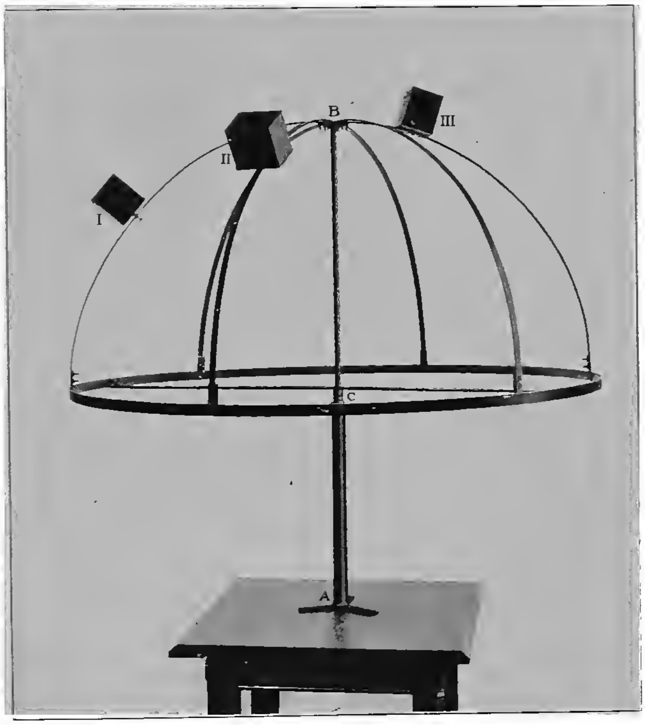


PLATE IV.



STELLINGEN.

STELLINGEN.

I.

Het „aardlicht" is hoofdzakelijk een gevolg van een permanent poollicht.

II.

Voor de meteorologie zoowel als voor de astronomie zijn helderheidsbepalingen van den hemelgrond van belang.

III.

De poollichttheorie van ARRHENIUS geeft geen voldoende verklaring van de verschijnselen.

IV.

Bij den tegenwoordigen stand der astrophotometrie zijn helderheidsschattingen (z.g.n. eye-estimates) niet overbodig, zooals MÜLLER en KEMPF willen doen voorkomen.

V.

Men behoorde er naar te streven de photometrie zooveel mogelijk te gronden op de photometrische wet der afstanden.

VI.

Uit de waarnemingen is niet gebleken, dat voor verschillende negatieve electronen, wier snelheid niet van de orde der lichtsnelheid is, $\frac{e}{m}$ een constante waarde heeft.

VII.

Het is niet waarschijnlijk, dat een atoom is een dynamisch stelsel van electronen, analoog aan ons zonnestelsel.

VIII.

De ellipsoïdische snelheidsverdeeling der sterren volgens SCHWARZSCHILD is identisch met de twee-sterstroom theorie van Prof. KAPTEYN.

IX.

Het beste uitgangspunt voor de methode der kleinste quadraten is het tweede bewijs van GAUSS, waarbij de middelbare fout minimum wordt gemaakt.

X.

Als men geen reden heeft een van twee gebeurtenissen meer te verwachten dan de andere, mag men nog niet aan die gebeurtenissen gelijke kans toekennen.

XI.

Bij het overgaan van de rekenkunde tot de algebra dient men niet te doen, alsof er twee nieuwe soorten van getallen worden ingevoerd: de positieve en de negatieve.

XII.

De bewijsmethode, welke door DERKSEN en DE LAIVE in hun leerboek der rekenkunde: *Theorie en Praktijk*, *dl. I*, *p.* 106—111, wordt gevolgd voor de herleiding van repeteerende tot gewone breuken, is onjuist.

XIII.

De begrippen verschuiven, draaien en omleggen van figuren dienen in de leerboeken der vlakke meetkunde gedefinieerd te worden.

XIV.

In de leerboeken over waarschijnlijkheidsrekening wordt aan het theorema van BAYES te groote waarde toegekend.

XV.

Op onvoldoende gronden beweert Turner, dat het feit, dat bij photographische steropnamen de indrukken niet evenredig zijn met den belichtingstijd, een gevolg is van een cosmisch verschijnsel.

XVI.

Uit het feit, dat volgens de gegevens uit *Publ.* **18** *Astr. Lab. Gron.* het quotient $\frac{\text{aantal sterren helderder dan magn. } m+1}{\text{aantal „ „ „ „ } m}$ (ongeveer) 3,5 in plaats van 4 is, leidt Turner ten onrechte af, dat er lichtabsorptie in de ruimte bestaat.

XVII.

Ten onrechte meent Turner, dat de waarde, die Newcomb gevonden heeft voor het totale licht aller sterren, bewijst, dat voor sterren, zwakker dan $12^{m}.0$, de gegevens uit *Publ.* **18** *Astr. Lab. Gron.* onjuist zijn.

XVIII.

Newcomb's bewijs voor de stelling, dat de sterren met grootere E. B. regelmatig over den hemel verspreid zijn, is onvoldoende, omdat de beschouwing der plenitudes wordt verwaarloosd.

XIX.

Het bewijs, dat Kobold levert voor de stelling, dat de sterren van Type I naar den Melkweg toe niet in aantal toenemen, is foutief.

XX.

In „de Gids" van Mei 1871, p. 277, zegt Prof. C. B. Spruyt:

„Nog minder kan ons de zuivere wiskunde opleiden tot die nauwkeurigheid in onze „redeneeringen, waarvoor hare beoefening volgens zoovelen het aangewezen middel zijn „zal. Want bij alle wiskundige redeneeringen zijn, volgens de juiste opmerking van „Hamilton, de twee fouten onmogelijk, die in bijna alle valsche redeneeringen de „onjuistheid der conclusie veroorzaken. Die twee fouten, die beiden hunnen laatsten „grond vinden in gebrek aan oordeel, zijn onnauwkeurige waarneming en dubbelzinnig-

„heid der gebruikte woorden. Daar de wiskundige niet observeert, maar alleen de „constructies aanschouwt van nauwkeurig bepaalde begrippen, is de eerste fout bij eene „wiskundige redeneering niet mogelijk. Daar iedere term in zijn wetenschap beantwoordt aan een nauwkeurig omschreven begrip, kan ook de tweede fout geen invloed „hebben op de juistheid eener wiskundige beschouwing . . . . .

„Buiten de ontwikkeling van het voorstellingsvermogen kan de mathesis ons geene „andere psychische werkzaamheid leeren dan die, welke gevorderd wordt om uit ondubbelzinnige praemissen eene juiste conclusie te trekken. Maar deze psychische werkzaamheid is zoo uiterst eenvoudig, dat geen mensch zich daarin kan vergissen."

Dit oordeel is onjuist.

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